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THE HAPPY PAIR.*

ADDRESS OF GEORGE WHARTON PEPPER, ESQ.,

at the Preview of
The Museum of Science and Industry,
Chicago, Illinois, April 14, 1939.

On behalf of my visiting fellow Managers of The Franklin Institute of Philadelphia I return thanks for the generous hospitality which is being extended to us.

It is a very unusual occasion which brings together in Chicago these two groups of guests from New York and from Philadelphia. We have come here because of our common interest in your community undertaking. We have come also

* On April 14th, in response to an invitation from the Commercial Club of Chicago, and through the hospitality of Mr. Lessing Rosenwald of Philadelphia, eighteen of the Board of Managers of The Franklin Institute attended a preview of the Chicago Museum of Science and Industry, together with representatives from the governing body of the New York Museum of Science and Industry.

Following a reception in the morning the groups had luncheon in the cafeteria of the new Museum, and the afternoon was spent in an all too short inspection of its Halls.

This Museum, devoted to a visual demonstration of the past and present of science and industry, occupies the magnificent structure erected as the Fine Arts Building for the Chicago Worlds Fair in 1893. About 600,000 square feet of floor space is available which is just being filled with exhibits following modern methods of presentation technique.

In the evening a formal dinner was given by The Commercial Club at which the principal address, which we print here, was given by Hon. George Wharton Pepper, a member of the Board of Managers of The Franklin Institute.

(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors in the JOURNAL.)

to pay our tribute to the memory of the far-seeing philanthropist whose generosity made possible the great Museum about to be opened to the public. Many of us are sure that the spirit of this occasion means intimate future relationship and a measure of happy coöperation between the three great Museums of Chicago, New York and Philadelphia. Certainly the sons of the founder of the Chicago Museum are maintaining the standard of generosity which won for him a unique place on the roll of great philanthropists.

It is a thrilling experience for a Philadelphian to visit Chicago. In our naïve and provincial fashion we Philadelphians are quite ready to admit this. Whether a visiting New Yorker will concede that thrills are to be had outside of his right little, tight little Island, I do not hazard a guess. Nor am I prepared to specify the characteristic differences between the inhabitants of the three cities. When I was young everybody wanted a ring-side seat to watch Dana of the *New York Sun* as he showered devastating blows upon Godkin of the *New York Evening Post*. It was Joseph Choate, I think, who observed at that time that it was very hard to be good in New York when the *Sun* in the morning made vice so attractive and the *Post* in the evening made virtue so repulsive. But that is a note from a far distant past. The New York of today is the home town of all sorts of worthy causes and we are being led to expect great things of the World's Fair, which is about to burst upon us in all its glory. That mirth-provoking periodical, the *New Yorker*, has recently defined a Philadelphian as a relaxed Bostonian; but I think that a typical Chicago man would have to relax himself beyond recognition before he could attain the philosophic calm which is supposed to be the Quaker birthright. And even to contemplate any sort of resemblance to a Philadelphian would probably make a New York man—or more particularly a New York woman—grow prematurely gray!

It is more satisfying to emphasize points of agreement between these three American communities than to lay stress on their differences. And the point of hearty accord between them which is uppermost in my mind tonight is the conviction that Science and Industry are well suited to one another and that, when mated, they make a Happy Pair.

It must be a relief to you to find that my announced topic, "The Happy Pair" refers to the union of Science and Industry and not to the Senatorial device of matching votes, or to any of the other Pairs which occupy public attention—either in Washington, at Hollywood or elsewhere.

Indeed, this happy occasion is not unlike a wedding party. Friends and relatives of the newly-weds have come a long way to take part in the festivities and to wish the Happy Pair a long life and a merry one in the Old Homestead which has been prepared for their reception.

What a wonderful home it is! I first came to Chicago as a young lawyer just fifty years ago. That was a thrilling experience; but the visit that gave me my greatest thrill came a few years later when the Columbian Exposition of 1893 so satisfied my imagination that nothing seen since seems quite comparable to it. The two features that stand out most prominently in memory are the Court of Honor and the Fine Arts Building. I remember wishing that at least the building might be preserved for all time; but I did not suppose that this could really happen—nor did I even dream that the privilege would be mine of taking part in the ceremony of permanent dedication.

I referred a moment ago to Science and Industry as "newly-weds." I spoke advisedly, for only in the relatively recent past has the union of these two been cemented.

For a long, long time Science was a crusty old bachelor. He was an independent and self-satisfied old chap, rather patronizing in his attitude toward things in general and especially toward things of the spirit. There was even an open warfare between Science and Religion. God-fearing people thought it necessary to treat Science as an enemy and the investigations of men of Science as a menace. The godly were afraid that the astronomers would injure the stars.

Meanwhile Industry was approaching marriageable age and was manifesting charms which even a seemingly confirmed old bachelor could not ignore. I do not know just how or when Science and Industry first met. It was long ago, as we mortals reckon time, but in the calendar of Science a thousand years are but as yesterday. If they had met among the Pennsylvania Dutch folk in my native State the introduction

would have been simple and inexpensive. Among those practical-minded people it was long the custom for the parents of the girl to give notice that she was of marriageable age by painting the gate-post blue. This was a colorful and delicate suggestion to eligible bachelors that they might call and be sure of a welcome. I assume that in some such discreet way Industry allowed Science to be made aware of her—and when this had come about it became a case of love at first sight. Science began to realize how relatively sterile had been his previous achievements—and Industry blushingly admitted that Science was the man of her choice. And so they were married and were not slow to discover that life for both of them had suddenly become a richer and happier existence.

Early in their married life the Happy Pair learned what each could best contribute to the domestic partnership. Science, congenitally a hunter, applied himself with renewed vigor to discerning the laws of Nature. As and when he bagged them, he brought them home to Industry, his waiting spouse, and she deftly applied them to the needs of man. This division of labor—this differentiation of function—is recorded in the inscription which appears around the base of the dome of their new Chicago home.

I say "Chicago home"—for while the Happy Pair are domestic in their tastes they have a restless curiosity which forbids them to settle down exclusively in one place even if it be such a palatial residence as that in Jackson Park. Thus they recognize the American Institute of the City of New York as one of their metropolitan homes. We of The Franklin Institute have made them feel quite at home in Philadelphia, where the vitality of the Franklin tradition has its maximum power. Sojourning now here and now there the Happy Pair will take delight in exhibiting to an eager public the fruits of their union. Nobody would be so ungallant as to speak slightingly of the Dionne household, but the progeny of Science and Industry are as the stars in the sky for multitude. Perhaps I had better not carry my Parable too far—for I am in danger of crediting the newly-weds with a larger family than is conventional. However, "newly-wed" is a relative term: and (as I said a moment ago) decades and centuries are the seconds and minutes of Science. At any rate it must be a great satis-

faction to the Commercial Club to have been from the outset the sponsor of the Chicago branch of this interesting family. If the duties of a sponsor for a great Museum are anything like those of a sponsor in baptism the Club will be kept busy individualizing the members of the growing family of exhibits and supervising their development and growth.

The task of the sponsor will of course be lightened and simplified by the good judgment of the officers and trustees of the Museum with President Dawes at their head and by the efficiency of Director Philip Fox and the rest of the Museum Staff. They may be trusted to insure lives of usefulness for the exhibit-children of the Happy Pair and to make it certain that they will not luxuriate in idleness. President Dawes has expressed the ideal of the Chicago Museum in so admirable a fashion that no doubt the officers of the Museum in New York and certainly we of The Franklin Institute in Philadelphia can join in a hearty "amen." This is what Rufus Dawes has written:

> "It is the function of the Museum of Science and Industry to explain the methods whereby science discovers, genius invents, and industry applies the facts and the laws of nature to be used in the forward march of civilization. This it attempts to do not in static, lifeless exhibits, but in living, moving demonstrations of precision, beauty, and color.
>
> "The exhibits not only show what has been accomplished in successive steps of progress but explain why and how these accomplishments have been made. The full achievement of this objective can be obtained only with the active coöperation of industry, but when, by such coöperation, it has been attained, the Museum of Science and Industry will contain the full explanation of the differences between ancient and modern civilization The exhibits will stimulate the intellectual curiosity and bring the public to a better knowledge and understanding of the progress that has been made, and of the greater improvement that may yet be attained in the living conditions of men by the coöperation of science and industry."

I am glad that Mr. Dawes has thus emphasized the practical necessity of securing the coöperation of industrialists because we must not shut our eyes to the financial problem of Museum maintenance. I should think that some measure of coöperation between the three great Museums themselves might easily stimulate the interest and enlist the support of far-seeing industrialists. If the same movable exhibit, illustrative of some great industrial achievement, could be displayed in sequence in each of the three Museums the value of the display to the exhibitor would be many times multiplied. If objects of historic significance could temporarily be exchanged between the Museums the objects would produce their educational effect upon a greatly enlarged class of students.

Perhaps I am wrong in supposing that there ever is such a thing in Chicago as a financial problem. Perhaps it is only in the effete east that the struggle for financial support is a matter of concern to Museum Managers. In any event we must be on our guard against commercializing our institutions. Even the struggle for existence cannot be permitted to lower our standards. Our favors are not for sale. The fact that this great Chicago Museum is sponsored by the Commercial Club does not mean that the Museum has a commercial aspect but rather that the members of the Club are animated by scientific interest. We must always spell Science and Industry with capital initials. But, even so, a captain of industry cannot be indifferent to the fact that the Happy Pair recognizes his product as a child of their marriage and one of which both parents are justly proud.

It is not only against commercialism that we must guard. There is also the danger that institutional self-consciousness will convert these Museums into selfish rivals. This danger must be averted. It will best be averted not by schemes of organic union but by the cultivation among the three groups of Managers of the spirit of fellowship in a common enterprise which marks this gathering tonight. Each of us must be ready to give the others the benefit of ideas and experience which in practise have been found useful. We in Philadelphia are the happy inheritors of the Franklin tradition. This is of immense value, because the Museum may become a sort of

reincarnation of the great American and where his spirit lives there can be neither backwardness nor provincialism. We are actually trying to re-awaken popular interest in the Homely Virtues of which he was the embodiment—honesty, industry, thrift and good citizenship. I could almost wish that the Franklin name were not so definitely attached as it is to our Philadelphia Museum, for in point of fact the development of all three museums is a living manifestation of Franklin's spirit and we are all engaged in what is essentially a Franklin Movement. Each of our three management groups will need all the helpful coöperation that is available for we shall be responsible for the up-bringing not only of the children already in being but for the nurture of future children of the Happy Pair. We must not so focus attention upon past achievement as to keep us from looking ahead. We must, in Browning's phrase, always be contrasting the Petty Done with the Undone Vast. Great as have been the achievements of Science in the past I have no doubt that the future holds greater wonders in store.

Whenever I want an apt quotation applicable to the situation of the moment I turn to Benjamin Franklin. He never fails me. Said he: "The world is daily increasing in experimental knowledge, and let no man flatter the age with pretending that we have arrived at a perfection of our discoveries." A backward glance will suggest to us what later a forward gaze may disclose.

The 17th Century, the age of Galileo and Newton, produced the union of mechanics and astronomy—and this in turn gave us improved methods of navigation and more accurate artillery. The next period, coincident with the 18th century, supplied new theories of chemistry and heat, followed by the invention of the steam engine and the development of many uses of localized power in manufacture. Then came the 19th century during which these new theories were applied in practise. At the turn of that century we were startled by the development of distributable power in the form of electricity and of mobile power in the internal combustion engine. Immediately there followed the unification of physics and chemistry and the complete revolution in scientific theory which we have been witnessing during the last few

decades. Thus up to today we have lately accumulated vast stores of theoretical knowledge. Tomorrow we shall begin to see its practical applications in social and industrial life.

What will these new children of the Happy Pair be like? Some of them will appear as new materials. Others of them will be new processes. I have recently read a little book styled "The Frustration of Science," a symposium in which competent English scholars give their views of the future of Science and Industry. In this volume sunlight and shadow succeed one another in somewhat bewildering fashion. Sunlit spots are those parts of the work which envision strange and wonderful new materials and new processes. The dark spots are the passages in which are enumerated all the obstacles which politicians, industrialists, economists and ordinary people like you and me persist in placing in the path of progress. The writers seem to agree that most of us are more or less unconsciously conspiring to frustrate the complete and happy consummation of the union of Science and Industry. Nevertheless, in spite of their gloom, they concede that the union will not be barren. The union of Science and Industry is no shot-gun marriage. It is the result of natural affinity and free choice. We are thankful that at least in this country the two have not been paired by the imperious compulsion of dictatorship or by the dictates of that early stage of Fascism which is euphemistically styled Planned Economy. A qualified scholar, speaking before the American Philosophical Society, recently observed that "Science and the relatively free initiative possible in our democracy have, despite difficulties and maladjustments, given us an unprecedented prosperity shared as never before by the great masses of the people. We should jealously cling to, preserve and foster the science and democracy that have produced this!" The children whom even the gloomiest scientists predict for the Happy Pair are quite numerous enough to keep our Museums teeming with life and seething with activity. Those children will be producing materials with the properties they desire instead of doing the best they can with materials already at hand. As for new processes in life, we are told to expect whole towns under glass roofs without visible support, with weather made to order and clothing

discarded as no longer useful. "For a long time," writes one of these prophets, "people would probably be conventional enough to cling to the old habits particularly the desire for privacy, but in the long run," he more hopefully proceeds, "the greater convenience and freedom of the new environment would be bound to lead to a new social life."

I fear that I shall not survive long enough to see Chicago, New York and Philadelphia under glass. I hope that I shall not live to see all three transformed into nudist communities. Much as I admire my fellow-citizens of both sexes I distinctly prefer to cherish some illusions and not to see them as they are. I am certain, however, that short of the realization of these particular prophecies, our Museums will be fairy lands of Science even in greater richness and variety than they are today. I am confident that their Managers will be hospitable to every new and useful development and that the Museums themselves will fill a larger and larger place in municipal life.

Today we have inspected with immense satisfaction the great building which has been aptly styled the most impressive horizontal classic composition in America. In it we have followed step by step the course of the technical ascent of man. We began with Physics and Chemistry. We followed along through Geology and Mining, through Agriculture and Forestry. We were witnesses of the evolution of Power, an evolution which proceeded from muscles to electricity. Next, in Transportation, we saw Power in action; in Architecture we gazed at what Ruskin styled Frozen Music; and we ended our preview with Civil Engineering, the Medical Sciences and the Graphic Arts.

We had seen more than we could absorb and yet we came to the end of our cultural pilgrimage with regret.

In like manner we who are your guests come tonight with equal regret to the end of our sojourn in your midst. We have much to thank you for and much upon which to congratulate you. But above all else we here pay our tribute of respect to the memory of the Founder and we predict that the people of your great city will be better equipped for life and better prepared for good citizenship because they are hereafter to be the friends and neighbors of the Happy Pair.

Science and Freedom.—DAVID SARNOFF, President of Radio Corporation of America, stated before the American Association for the Advancement of Science at Richmond, Va., recently, "Business men are learning that industry, commerce and finance must publicly proclaim their objects and their methods, and must justify even their highest purposes if they are not to be misunderstood. In the domain of science the task of public education and explanation must be solved by your collective efforts rather than by individual action. It is a problem calling for coöperative solution by any group of earnest men whose purpose is the advancement of their profession and their ideals. Every advance in scientific knowledge, every successful experiment—no matter how remote it may seem from human affairs—finds its end result in goods and services for mankind. The scientist who would split the atom may regard himself as a worker in a monastery, but he is mistaken. In reality, he stands at the head of a moving belt, an assembly line so long that the eye cannot see the end. The product of his brain is augmented and shaped by the minds of millions of other workers, each dedicated to a single operation in the endless mechanism of production. No scientist can deny his close kinship to these other workers, and his own dependence on their labors. Recently an Englishman proposed a moratorium on new inventions for a period of five years. It is by no means a new idea: that the ability of science to create has outstripped the capacity of man to assimilate; that we need a breathing space to adjust ourselves to a new physical environment, to let our economic development catch up with the progress of science. What the world needs today is more science, not less. But technical science alone cannot bring out physical and social progress into harmonious relation. It must be reinforced by social science, equally persistent and efficient. The interdependence among all men has created the need for social science, and for better social understanding by the leadership of science, business and government."

R. H. O.

SOME CONTRIBUTIONS OF RADIO TO OTHER SCIENCES.*

BY

J. H. DELLINGER,

National Bureau of Standards.

Radio is a young science. It got its start in life by borrowing heavily from its friends both the small change of instruments and techniques and the large bank credits of basic principles and new discoveries. Has it discharged its early debt, and does it pay its current bills for services rendered today by its fellow sciences?

Like man, no science liveth unto itself alone. Radio science makes constant use of the techniques and principles of other sciences. To illustrate: the understanding and development of antennas depend on knowledge of physical optics and the theory of wave radiation. The evolution of the electron tube employs the sciences of electrostatics and electrodynamics. Radio devices in general depend on the principles of alternating currents. Insight into radio wave propagation comes through study of electrons, photoionization, and the composition of matter as it exists in the high atmosphere.

But the borrowings of radio are far outweighed by the returns it is able to make not only to the sciences, but to the arts and many other branches of human activity. Everyone knows how radio contributes a useful tool or technique to many of the useful arts and some of the fine arts.

To cite a few examples, we all know how the high art of government is being remolded by the powerful tool put into its hand by radio broadcasting. The potential control of human relations through entirely new possibilities of mass psychology is one of the portents of our times. Related to this are the amplifier and the loud speaker. The elimination of the problems of auditorium acoustics is remaking the arts of oratory and of singing. To the finest of the arts, music, new

* Presented at a meeting held Thursday, December 8, 1938. Publication approved by the Director of the National Bureau of Standards of the U. S. Department of Commerce.

vistas are opening through new types of musical instruments and extensions of ranges and control, all provided by radio techniques.

Time measurement has been made so precise by radio devices as to reveal an effect of the motion of the moon on the rate of accurate pendulum clocks and even to discover variations in the rate of rotation of the earth on its axis. The art of the physician is notably advanced by radio-frequency devices which permit treatment in the very interior of the tissues of the human body. Television has become a reality through the development of photoelectric and cathode-ray tubes.

A single radio device, the electron tube, has grown so great that politicians squabble over it. In recent patent litigation, the Attorney General of the United States said this "is the key device which is essential to the operation of modern telephone and telegraph wire networks; to radio transmission and reception; to sound motion pictures, to the transmission and reception of images by television or wire photography; to public address systems; to diathermic medical treatment; and to electric power transmission. There is no substitute for it, and without it the modern electronics industry could not function."

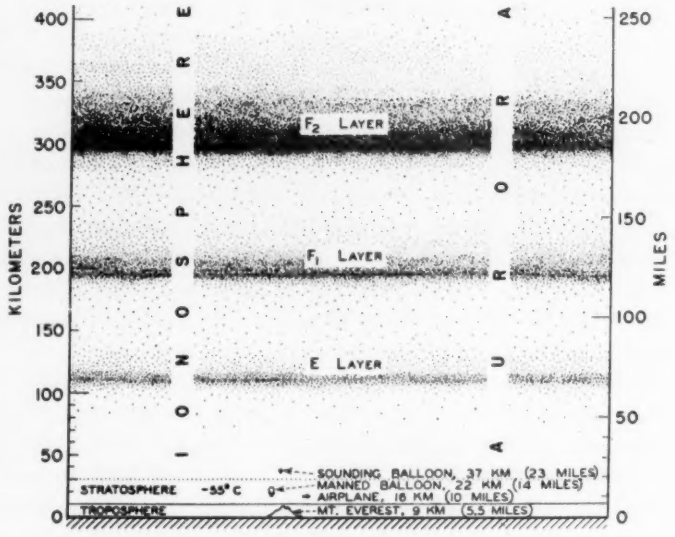
The C. and P. Telephone Co. recently published the following statement under the title, "The Voice of Stentor":

"If you were to make a telephone call around the earth (as has been done for experimental purposes) your voice would be amplified approximately 1,000,000,000,000,000,000,-000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,-000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,-000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,-000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,-000 times."

Though you may read this statement you can not remotely realize it. A billion dollars is such a vast sum as to be quite beyond our comprehension, yet see what a puny part of this figure a billion is. I know of nothing in mathematics or physics more impressive.

All this however is quite subordinate to the theme of this paper. The contributions of radio to the arts are after all so well known as to need no telling. It has been my good fortune to be associated with some developments through which radio is directly aiding the advance in certain sciences. They are the large-scale sciences, of the general category of geophysics and astronomy. For radio waves operate outside the laboratory, along and above the surface of the earth, in and over

FIG. 1.



Structure of the atmosphere.

the earth's atmosphere. Specifically, the sciences in which the use of radio itself is contributing to progress are: the electrical properties and composition of the atmosphere, meteorology (i.e. the science of weather), terrestrial magnetism, solar physics, and astronomy.

Figure 1 gives a rough idea of the structure of the atmosphere. The maximum altitude reached by an airplane is 16 kilometers (10 miles), this record having been made by M. J. Adam, an Englishman, in 1937. An altitude of 22 kilometers (14 miles) was reached by the stratosphere balloon manned by

our Captains A. W. Stevens and O. A. Anderson in 1935. A small sounding balloon was sent up to about 37 kilometers (23 miles) by the National Bureau of Standards in 1938 (this was indicated height, not accurately verified). The highest mountain is shown as extending up to 9 kilometers ($5\frac{1}{2}$ miles) in the troposphere. The troposphere (from the Greek "trope," change) is that changeable region in which clouds form, convection is active, and in general weather is produced. The temperature drops as altitude increases in the troposphere until we reach the stratosphere throughout which the temperature is approximately uniform with altitude, varying somewhat geographically but averaging about 55 degrees below zero Centigrade. The dotted line at 30 kilometers ($18\frac{1}{2}$ miles) signifies the upper limit of direct measurement of temperature. Various theories of the temperature at higher levels disagree. Higher still are ionized regions which are important in radio wave transmission and in which aurora occurs. Here the molecules of air are split up into positive and negative electric particles called ions. This whole upper portion of the atmosphere is called the "ionosphere." Many of its characteristics are definitely known, which can not be said of the region between it and the troposphere.

Those variations of heat and moisture which are manifested to us as weather are caused by actions taking place in the troposphere, and influenced to an unknown extent by the winds or other actions in the stratosphere. The science of meteorology is therefore interested primarily in the troposphere and secondarily in the stratosphere. It is an extraordinary fact that although it has long been known that conditions throughout the entire troposphere determine weather, weather analysis and prediction have been limited almost entirely to knowledge of conditions in one plane, the lower surface of the troposphere. Extensive observations of temperature, pressure, and humidity at the earth's surface, and wind velocity not far above the surface, with no knowledge of their variations at higher levels, have been our resources for the forecasting of weather.

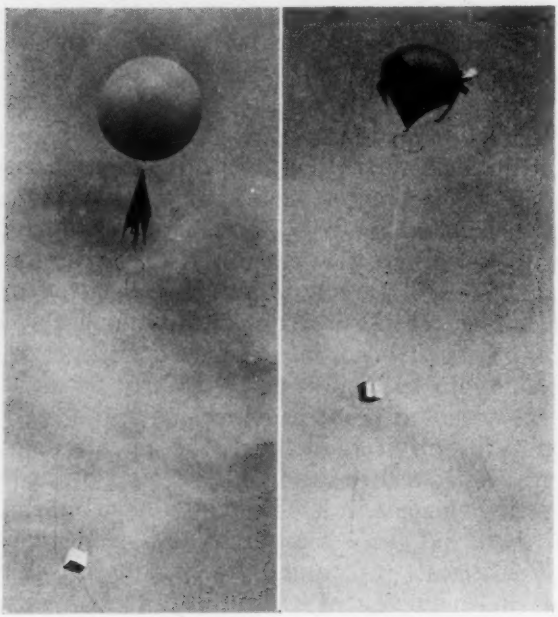
It has long been apparent that any radical improvement in weather forecasting must await the development of means for securing these data at least throughout the troposphere.

That means has now been developed, and is called the radio sonde (from the French "sonde," meaning sounding). A small balloon carries aloft the required weather indicating instruments and a radio transmitter capable of giving signals corresponding to the indications of the weather instruments. Everything is automatic, so the balloon does not need to be large enough to carry a man. The idea has been under active development during the past ten years in many countries. I shall describe particularly the form in which it has been developed by the National Bureau of Standards for the Navy Department during the past three years, and in which it is now being put into service by the U. S. Navy and Weather Bureau.

A rubber balloon, inflated with helium to a diameter of 4 or 5 feet at the ground, has suspended from it a small box in which are: a barometer, thermometer, hygrometer, additional weather instruments if desired, a radio transmitter, and batteries to serve as power supply. A wire for a radio antenna, and a small parachute for safe descent, complete the ensemble. The weather instruments each cause an electrical resistance to vary, in accordance with the changes of temperature, etc., as the balloon rises. In early forms, the three instruments actuated pointers which made repeated contacts with a uniformly rotating element, these contacts starting or stopping the radio transmitter. On account of the difficulties of the rotating element, it has been eliminated in the development with which I have been associated, and instead variations of electrical resistance are produced which cause variations in frequency of an audio current which in turn modulates the carrier frequency of the radio transmitter. Changes of atmospheric pressure move a contact over a switching unit. Carrier frequencies between 60 and 200 megacycles per second are used because they require only short antennas and low-power, light-weight apparatus. At the radio receiving station on the ground, a radio receiver is used to which is connected an audio-frequency meter and a graphical recorder. On a moving paper is automatically drawn a graph which continuously indicates the received audio frequencies, or, by proper calibration, the temperature, humidity, etc., at the balloon.

Figure 2 shows the device ascending and descending. Some distance below the balloon is the box containing the instruments. The parachute hangs just below the balloon on the ascent; on the descent, shown at the right, it supports the box and permits it to reach the ground without damage. The box, less than a sixth of a cubic foot, encloses a complete set of weather instruments (for temperature, pressure, and humidity), a radio transmitting station, and a power plant. The total weight is two pounds, and it is sold for about $25 (in lots of 2000). The balloon costs about $2, the parachute $1, and the helium $1.

FIG. 2.



Ascent and descent of balloon carrying radio sonde.

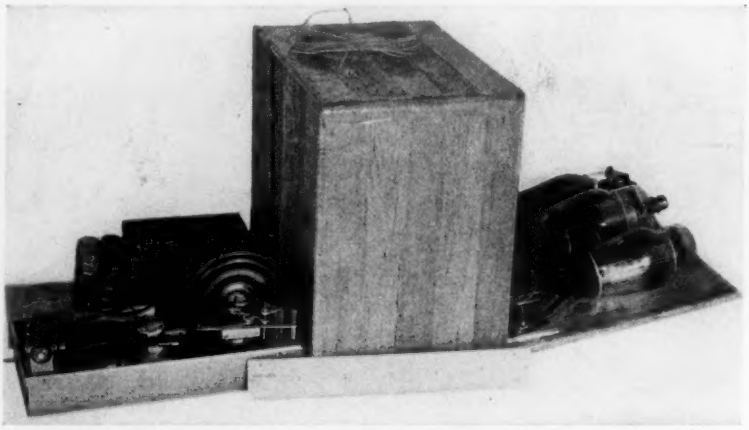
It is of course not essential that the equipment be recovered, but as a matter of fact about half of all sent up are found and returned to the owner. A number of people have had the pleasant thrill of seeing the radio sonde appear from the sky and settle to earth with its red silk parachute. One of

those sent up by my co-workers in Washington appeared among the bathers on the beach at Atlantic City, and one settled on the deck of a vessel in Delaware Bay.

A 1937 experimental model of this radio sonde is shown in Fig. 3, opened out to show the interior. The box is of balsa wood. The barometric element and switching unit are at the left, with the batteries behind them. The three-tube radio transmitter is at the right.

In a more recent model the radio transmitter has been reduced to a single tube. It is mounted, as in Fig. 4, above

FIG. 3.



Radio sonde (experimental model), opened out to show pressure device, batteries, and radio transmitter.

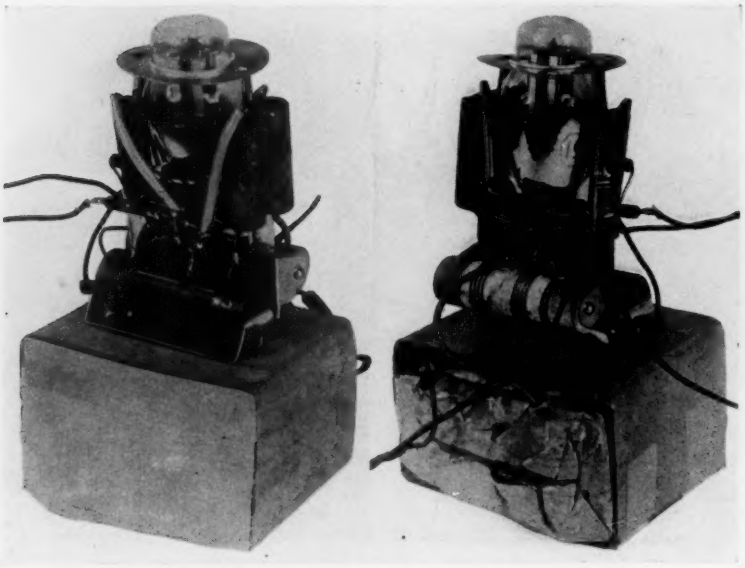
the thermally insulated compartment containing the batteries. Fig. 5 shows the aneroid barometric unit, with its pointer moving over a series of contacts to switch in and out the other instruments. Each contact identifies and, by means of a calibration prior to the ascent, gives directly a particular value of air pressure. This is the heart of the system, replacing the rotating element used in other forms of the radio sonde.

Figure 6 shows the *V*-shaped capillary glass tube containing a solution (hydrochloric acid, cuprous chloride, alcohol) which constitutes the temperature resistor, and below it a set of expanding hairs for humidity measurement. The expan-

sion of the hairs moves a cam contacting a resistor shown in the middle of Fig. 5. An electric hygrometer is being developed to replace the hair device; it utilizes the variation of electrical resistance of a lithium chloride film.

The radio sonde is useful for measuring a great variety of quantities in the atmosphere. Besides temperature, pressure, and humidity, it is adaptable to measure such things as

FIG. 4.

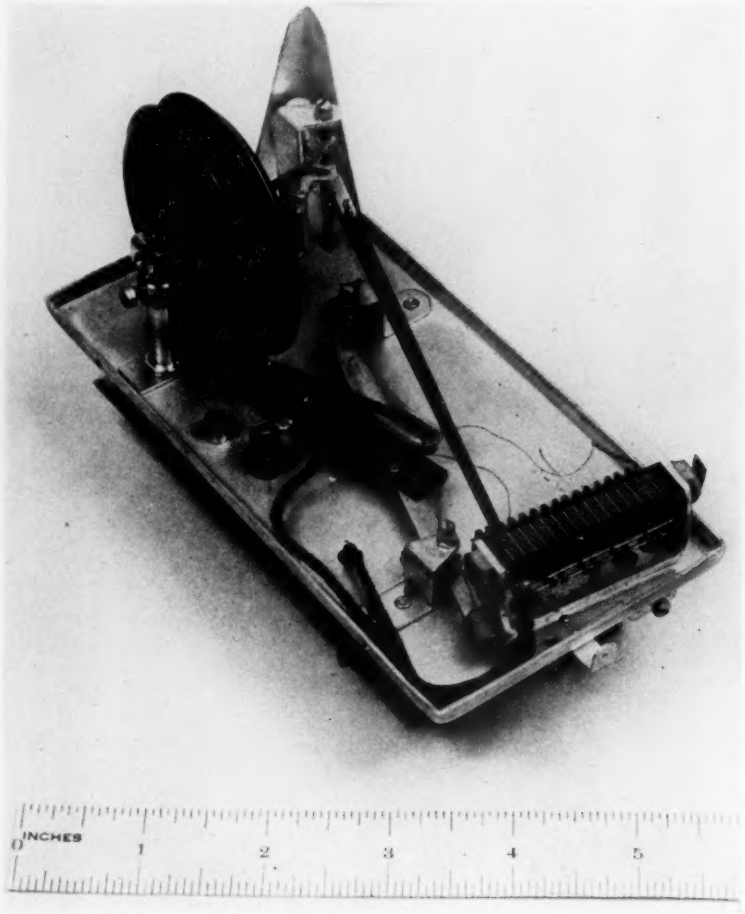


Single-tube radio transmitter as used in 1939 model of radio sonde.

wind velocities, electric conductivity, voltage gradient, brightness, cosmic rays, and ultraviolet radiation intensity and spectral distribution. From the ultraviolet radiation measurements the distribution of ozone and possibly of other constituents of the atmosphere may be determined. To measure brightness or ultraviolet radiation, a photoelectric cell replaces the temperature or humidity element. When more than three quantities are to be measured a simple switch is provided to shift periodically from one to the other.

Figure 7 shows a graphical record made of a radio sonde flight in which six instruments were carried; one for pressure, one for temperature, one for brightness, and three for humidity.

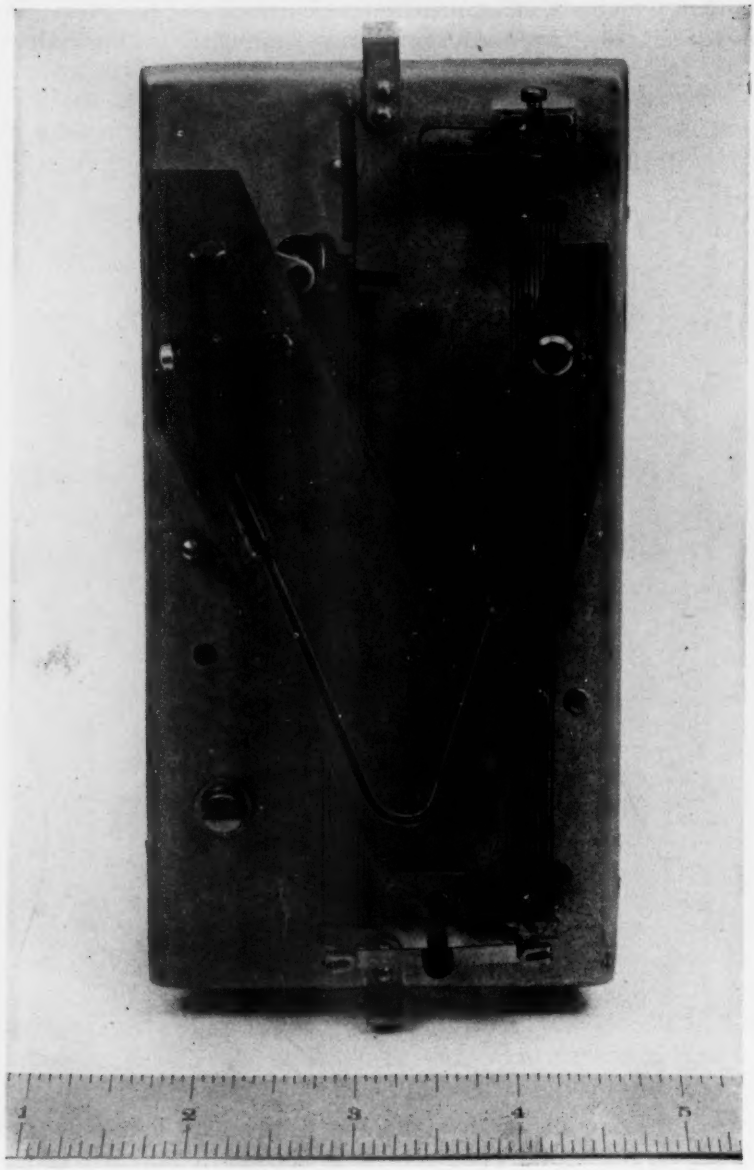
FIG. 5.



Barometric element and switch.

Two of the new electric hygrometers were being compared with a hair hygrometer. The record is shown in two parts; the portion of the ascent from 0 to 15 km. (50,000 feet) is at the

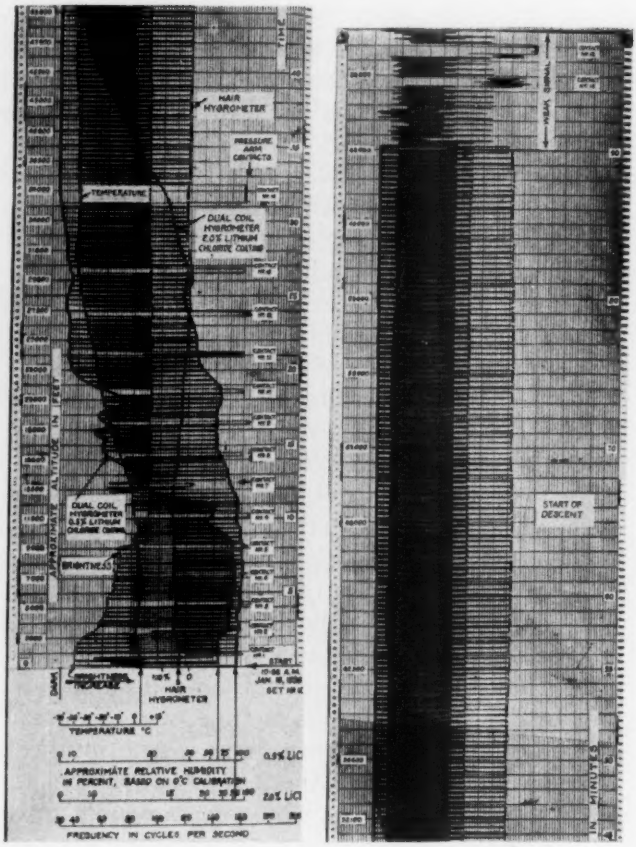
FIG. 6.



Temperature and humidity elements used in radio sonde.

left, and that for the further ascent up to 21 km. (68,000 feet) and then the descent, is at the right. The approximately horizontal lines show the swings of the recorder pen. The extremities of the swing have been connected by lines which

FIG. 7.



Record of a sounding of pressure, temperature, brightness, and humidity.

form the record of variation of the several quantities with altitude. The altitudes are given at the left in feet, and the time from the start of flight is given in minutes at the right. The recorded ascent and descent lasted an hour and 40 minutes.

The scales of temperature and brightness, and the three scales of relative humidity, are given at the bottom. The temperature dropped as the radio sonde ascended until above 9 kilometers (30,000 feet) it became constant in the stratosphere at about $-55°$ C. The day was cloudy, so the brightness increased gradually with altitude from the ground until at about 3 kilometers (9000 feet) there was a sudden increase of brightness as the radio sonde emerged from a cloud and the brightness remained constant thereafter. Emergence from the cloud is also indicated by a drop of humidity and a kink in the temperature curve.

Note the temperature inversion (i.e., point where the temperature ceases to drop with increasing altitude) at about 7 km. (23,000 feet) and also at 10 km. (33,000 feet). At each of these altitudes also the humidity drops.

The charting of the levels at which temperature inversions take place is one of the important new facilities which the radio sonde places in the hands of the meteorologist. Forecasting has hitherto been almost entirely on the basis of empirical relations deduced from pressure and temperature distributions observed in one plane. Now, with three-dimensional data it is possible to observe directly the interaction between the various air masses that go to make up the systems of high and low barometric pressure. These great air masses have different characteristics of temperature, humidity, and motion, depending upon whether they have their source from near the equator or the pole, and have moved over the land or ocean. They tend to maintain their individual identities over comparatively long periods of time, with the result that at their surfaces of contact they form discontinuities or so-called "fronts." It is along these frontal surfaces that the processes involved in weather phenomena are most active, and the study of them, called "air mass analysis," is providing means of really forecasting the weather. Their location is in part revealed by the observed temperature inversions and humidity changes. Temperature inversions are also significant in marking the tops of turbulent regions, haze, smoke, and cloud layers. Thus the prediction of thunder-storms, for example, is made markedly easier.

Air mass analysis has been attempted on a limited scale in the past, using data obtained from weather instruments sent aloft by kites and airplanes. Balloons have been used, too, depending on the chance that the instruments would come back to earth, land undamaged, be found, and be returned. All of these methods were prohibitively expensive for use on a large scale, unreliable, and limited in the heights practically attainable. Thus airplane flights for this purpose were only up to about 5 kilometers (3 miles), much higher than the altitudes usually used in commercial flying, but small compared with the 20 kilometers (12 miles) to which the meteorological services regularly send the radio sondes. The latter are so far from costly and so advantageous that they will be used more and more. The Weather Bureau uses them daily at 6 points in the United States now. This will be expanded to 20 or more this year, and eventually to 50 or more. Great value is attached also to the prospect of securing data from points in the polar regions and in the oceans, especially in hurricane and typhoon regions. Dr. Gregg, the late chief of the Weather Bureau, has stated that the regular use of the radio sonde will in fact mark the beginning of a new epoch in meteorological service.

While this development is gratifying, it is of perhaps even greater scientific interest to inquire what relations there are between meteorological conditions and radio wave transmission phenomena. Is it true, as you may have heard, that radio signals are louder and clearer on moonlit than on cloudy nights, or if not, is there any connection between weather and radio transmission? The answer is: no, there is little connection. Surprising though it be, I would almost say the two are quite independent. There are two demonstrated exceptions. One is an effect of those boundary surfaces between air masses called fronts. On account of differences in dielectric constant, principally due to water vapor and temperature differences, these fronts sometimes cause refraction of ultra-high-frequency waves, affecting their distance range and causing fading. There is a beginning of evidence, not yet conclusive, of such an effect at lower frequencies also.

The other effect of weather phenomena on radio transmission is "static," i.e., those ubiquitous atmospheric dis-

turbances which interfere with reception of weak radio signals. "Static" generally has its origin in thunderstorms. These storms may be nearby or may be hundreds or thousands of miles away. Every lightning flash is in effect a radio transmitter and sends out crashes of irregular radio waves. The fronts associated with hurricanes are sources of "static," so that hurricanes to a certain extent do their own weather reporting. By the use of radio direction finders at two or more points, and triangulating, some progress is being made in tracking hurricanes by means of the "static" accompanying them.

Except for these two effects, radio waves generally speaking ignore what is going on in the troposphere. They are vitally affected however by what goes on at higher levels, so much so that they are the means by which we learn the nature of the upper regions of the atmosphere. In the sketch of the atmosphere (Fig. 1), the shaded regions well above the troposphere and stratosphere constitute what is called the ionosphere. It is so high that there is really very little atmosphere there. The air pressure is actually less than a millionth of what it is at the earth's surface, so this region is the equivalent of an electric discharge vacuum tube. One of the striking things about such a tube is the display of beautiful light effects accompanying an electric discharge; interestingly enough we have the counterpart of this in the ionosphere, for in it occur those beautiful displays called the aurora borealis and aurora australis.

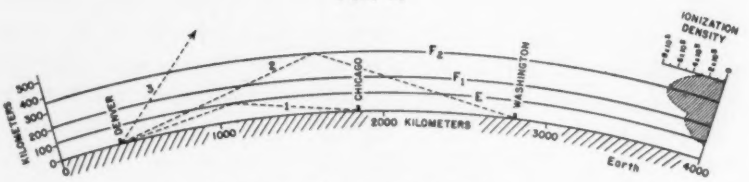
The very thinness of the air in the ionosphere, together with its direct exposure to all the radiations from the sun, explains its effect on the passage of radio waves. The air particles are separated so far from one another that collisions are far less frequent than in the lower atmosphere, and when an atom is ionized by ultraviolet radiation from the sun it remains ionized longer. As a result a large proportion of the air particles are in an ionized condition. When a radio wave passes through such ionized air the electric force of the wave accelerates the ions, which take on a certain amount of motion at the wave frequency, this accelerated motion in turn giving rise to radiation. There is thus an interchange of energy

between the ionized air particles and the radio waves, with a net effect of reflection or refraction of the waves.

It has been found from radio experiments that this ionized condition does not increase uniformly as the air pressure decreases with altitude. Because of varying distribution of chemical composition of the air with height, and because of the different gases' differing capability of absorption of solar radiation of different frequencies, there are certain strata or layers in the air in which a maximum of ionization exists, i.e., the ionization is greater than it is either above or below the layer.

Since the distribution of energy in the spectrum of radiation from the sun, and likewise possibly the chemical composition and temperature of the air at different heights, vary at

FIG. 8.



The principal layers of the ionosphere.

different times of the day and year, these reflecting layers in the atmosphere do not remain always at the same height. They vary diurnally, seasonally, and otherwise, in both height and ionization. There may be a considerable number of such layers at a given time. We find by radio experiments that there are ordinarily three layers in the daytime and two at night.

The structure of the ionosphere may be roughly visualized as shown in Fig. 8, which is for a typical summer daytime condition. This is drawn to scale, i.e., with the correct curvature, so the angles of reflection of radio waves from the layers may be properly estimated. The three layers are shown as mere thin lines, for simplicity. The layers have in fact a certain thickness, and the density of ionization varies within this thickness. At the right of the diagram is an illustration of a possible distribution of ionization density with height.

Dotted lines 1 and 2 indicate two of many possible paths of radio waves from a transmitter to a receiver as transmitted by reflection from the ionosphere layers. This picture, simple as it is, does in fact show how radio waves are transmitted over long distances. We know this from special experiments in which we measure the difference in time of arrival of a short sharp radio signal traveling by reflection from an ionized layer and the signal traveling along the ground. From the known distance along the ground and the known velocity of transmission of the radio waves (the same as the velocity of light), the height of the layer is calculated.

From these experiments we can determine not only the height but also the ionization density of the ionosphere layers. The higher the frequency of the radio waves, the greater is the density of ionization required to reflect the waves back to earth. The ionization density of a layer is proportional to the square of the upper limit of frequency of waves which can be reflected by the layer. To determine the ionization density it is then merely necessary to increase the frequency of the radio signals until that frequency is reached at which the signals are no longer receivable, and calculate the ionization density from that frequency.

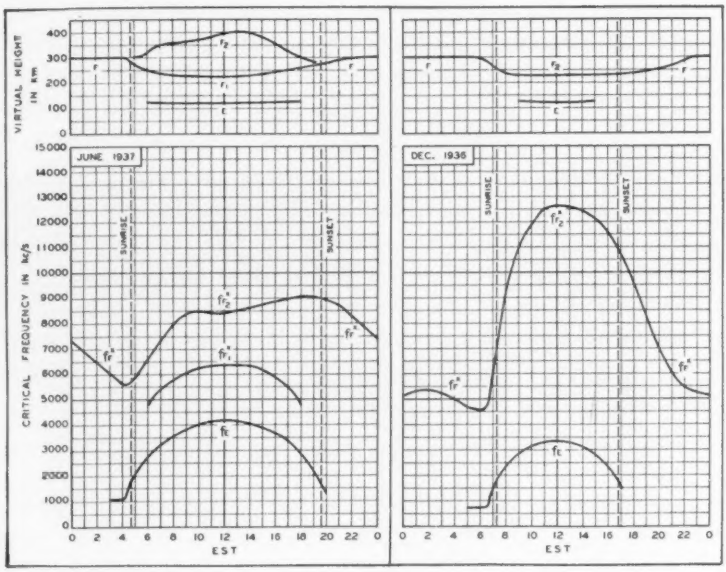
This radio technique is almost our only source of knowledge of the properties of the ionosphere. From the height and ionization densities of the layers, and their variations, it is possible to deduce speculative conclusions regarding the composition of the atmosphere at various heights. Thus we find radio to be the principal contributor to scientific knowledge of the composition as well as other properties of the higher levels of the atmosphere.

We know little about the detailed processes by which ultraviolet radiation from the sun produces and maintains the ionization in the ionosphere. We have however a large body of facts, from radio experiments, telling the variations of the heights and ionization densities of the layers, from hour to hour, from season to season, and from year to year. The facts of radio transmission can be summarized in far more compact form in terms of such ionosphere data than in terms of direct radio data. Knowledge of the behavior of the ionosphere is coming to be so important in the operation of

radio services that the National Bureau of Standards broadcasts ionosphere data by radio one day each week and publishes a summary each month. It may be necessary in the future to have such service daily from a number of places, like the weather forecasting service.

Figure 9 shows samples of the monthly averages of ionosphere heights and ionization densities, the latter ex-

FIG. 9.



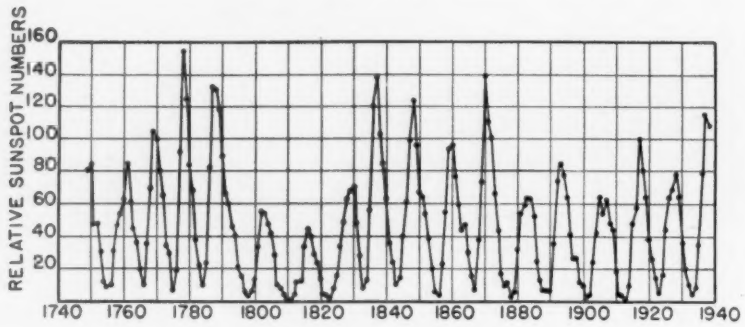
Typical summer and winter characteristics of the ionosphere layers.

pressed in terms of the equivalent critical frequencies, for typical summer and winter conditions. Values are given as a function of time of day, plotted as abscissas (0 = midnight, 14 = 2 P.M., etc.). Note that the F_1 layer exists in the summer day only. The E-layer height changes very little. The E-layer ionization (critical frequency) varies synchronously with the altitude of the sun, being highest at noon, and higher in the summer than the winter. The variations of the day F_2 and night F layers are more complex. The F_2 layer differs markedly from the other layers. It is much higher in

summer than in the winter, as though it were expanded by the heat, resulting in greater volume for a given number of ions and thus lower ionization density (critical frequency).

It would be expected that the ionization densities would vary from year to year because of variations in the sun. It has been known for a long time that the number of spots on the sun waxes and wanes in an approximate 11-year cycle. We have data on this for 190 years (Fig. 10). The results of radio work are now telling us that the sun's ultraviolet radiations, which are the principal cause of the ionization in the ionosphere, increase and decrease along with the sunspots. Neither the sunspots nor the ultraviolet radiations are the cause of the

FIG. 10.



The cycles of sunspot numbers.

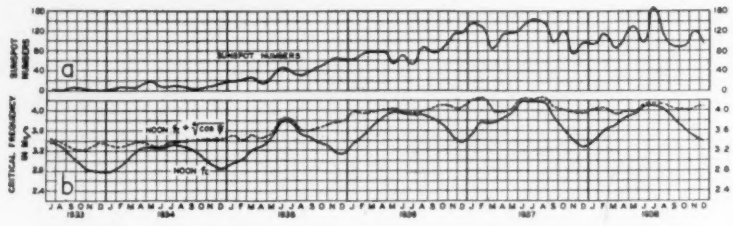
other, but both are manifestations of more profound activities inside the sun which undergo the 11-year variation. It is not possible to observe directly on the earth's surface the ultraviolet radiations which produce the ionosphere phenomena because they are absorbed in the ionosphere and cannot reach the surface of the earth. Sunspot numbers give merely a crude index of solar activity, and it seems likely that a much more fundamental index is given by the ultraviolet radiation intensity revealed through radio observations.

Compared with the 17 cycles or nearly two centuries of systematic observation of sunspots, our record of ionosphere observations is very short. In fact, continuous observations have covered only half a cycle, from the last minimum, in 1933, to the present.

Both seasonal and year-to-year changes are shown in Fig. 11 for the ionization of the *E* layer. The lower curve gives the average ionization at noon for each month since June 1933. The full-line curve shows the rise each summer and drop each winter, the climb to higher values each year, and also some minor fluctuations. To examine these three things separately, it is possible to redraw the curve with the seasonal variations (due to the changing angle of incidence of the sun's radiation) eliminated, and this has been done and plotted as the dashed curve.

For comparison, the upper curve gives average sunspot numbers for each month. The detailed correspondence of the dashed curve with sunspot numbers is impressive. It shows

FIG. 11.


SUNSPOT NUMBERS
a
b
NOON $f_0 = \sqrt{\cos\psi}$
NOON f_0
J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1933
1934
1935
1936
1937
1938

Variations of *E*-layer critical frequency, in comparison with sunspot numbers.

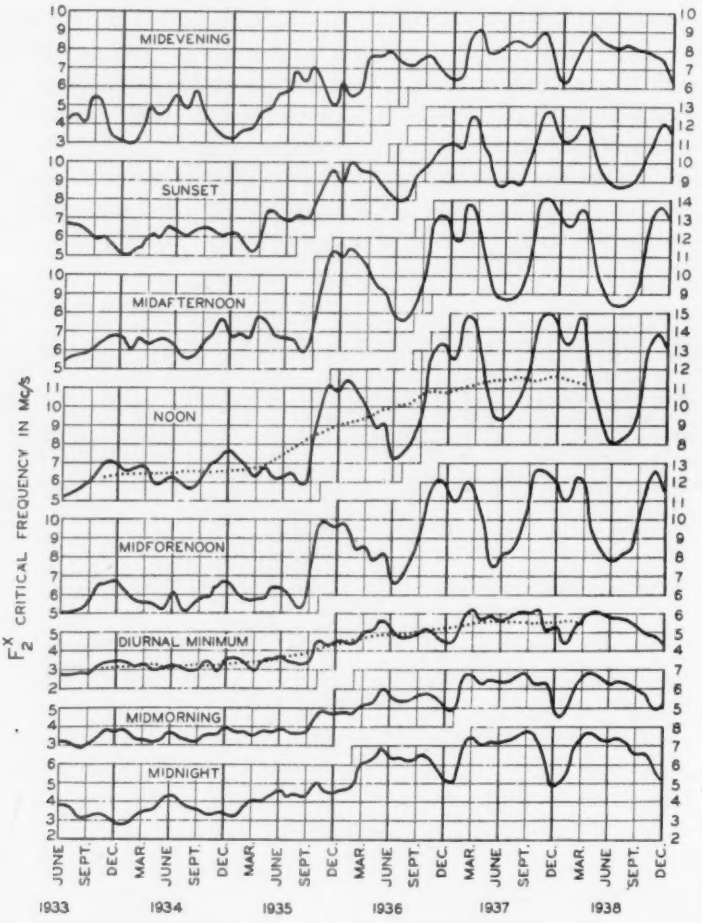
not only that the *E*-layer ionization follows the general trend of the sunspot numbers, but that the detailed changes from month to month show a fair agreement.

The F_2 layer presents a more complicated picture. No simple method exists for eliminating diurnal and seasonal variations as may be done for the *E* layer. Fig. 12 shows the variation, by average for each month, of the F_2 and *F* ionization for various parts of the day. All of these curves show the general rise in ionization superposed on the seasonal variation. The high daytime values in winter, and high night values in summer, stand out.

The year-to-year trend of the ionization of the layers is shown more clearly in Fig. 13. The general trend parallel to that of the sunspot numbers is striking. All had their minimum in 1933, and rose each year thereafter until 1938. Again

we see evidence that the sunspot numbers and the ultra-violet radiations which ionize the ionosphere have a close interrelation.

FIG. 12.

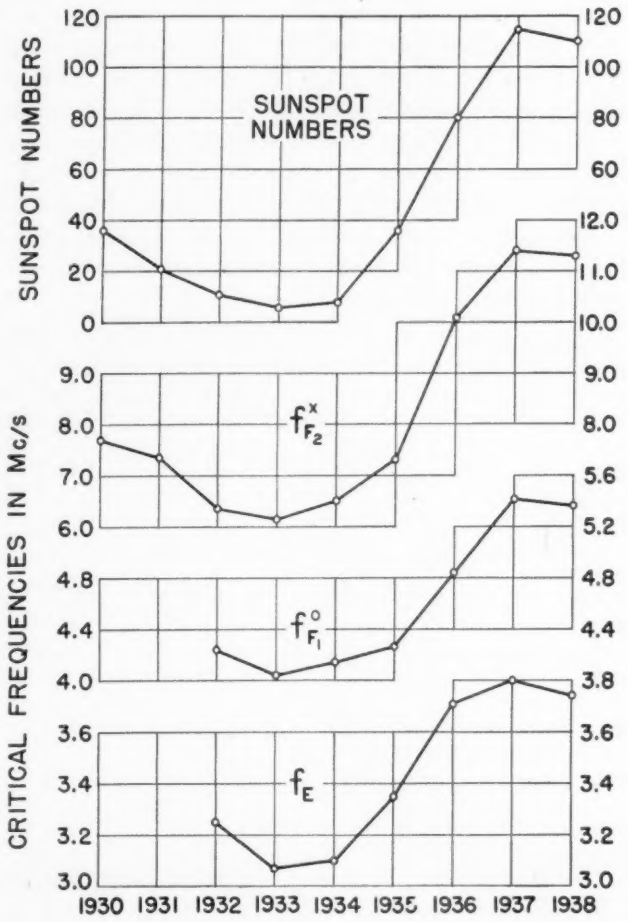


Variations of day F_2 and night F critical frequency.

At sunspot maximum the night F and day F_2 critical frequency averaged approximately twice its value at sunspot minimum. It follows that the F_2 ionization density was approximately 4 times, and the energy of the particular

ultraviolet radiations from the sun which cause the F_2 ionization was probably 16 times, as great at sunspot maximum as at sunspot minimum.

FIG. 13.



Annual averages of critical frequencies and sunspot numbers.

All this knowledge of the ionosphere not only has direct utility in radio work, but it also supplies the solutions to a number of geophysical puzzles. I have mentioned the expla-

nation it gives of aurora. Closely associated with that is the earth's magnetism. The earth has long been known to be a great magnet. Slight fluctuations in this magnetism are constantly going on. These fluctuations can only be due to electric currents flowing around the earth, but it has not been known hitherto where these currents are nor why they fluctuate. The ionosphere has recently supplied the answers. In the past two or three years we have, by radio experiments, been associating particular types of magnetic fluctuations with variations of the amount of ionization in particular layers of the ionosphere. The ions in these layers move, thus giving rise to currents which are in the aggregate very large. There are currents in the earth also, which fluctuate with the earth's magnetism, but these are secondary effects, induced by variations in the ionosphere currents.

Terrestrial magnetic disturbances, earth currents, ionosphere ionization, aurora, sunspots, and the sun's ultraviolet radiation, all increase and decrease together in an approximate 11-year cycle.

An outstanding type of magnetic fluctuation is known as the magnetic storm, which lasts one or more days. During one, the slight fluctuations of the intensity and direction of the earth's magnetic field and of earth currents are markedly increased. This increase occurs all over the world, but is most marked near the magnetic poles. At the same time it is found that there are great changes in the F_2 layer of the ionosphere; the magnetic storm is really only one manifestation of what may be called an ionosphere storm. When the storm begins, aurora is seen farther south than usual. Radio signals become erratic, being transmitted with good intensity for short periods, interspersed with periods of complete failure. This shows that the F_2 layer is turbulent, having small unstable patches or "clouds" of high ionization. Following the turbulent period, radio signals become weaker, and are entirely wiped out on the very high frequencies which depend upon high ionization density. The F_2 layer acts as though it were heated; it expands and thus its ionization density decreases and its height increases. The E layer is usually free from these effects; it is concluded that the electric

currents causing ionosphere storms or magnetic storms are mainly in the F_2 layer.

Another type of magnetic (and earth-current) perturbation, on the other hand, is found to be caused by electric currents below the E layer. This type is associated with a sudden type of ionosphere disturbance, and has markedly different characteristics from the magnetic storms. It lasts only a short time, minutes rather than hours or days, its effects are more intense at the equator rather than at the poles, and it occurs only in the sun-illuminated hemisphere rather than over the whole earth.

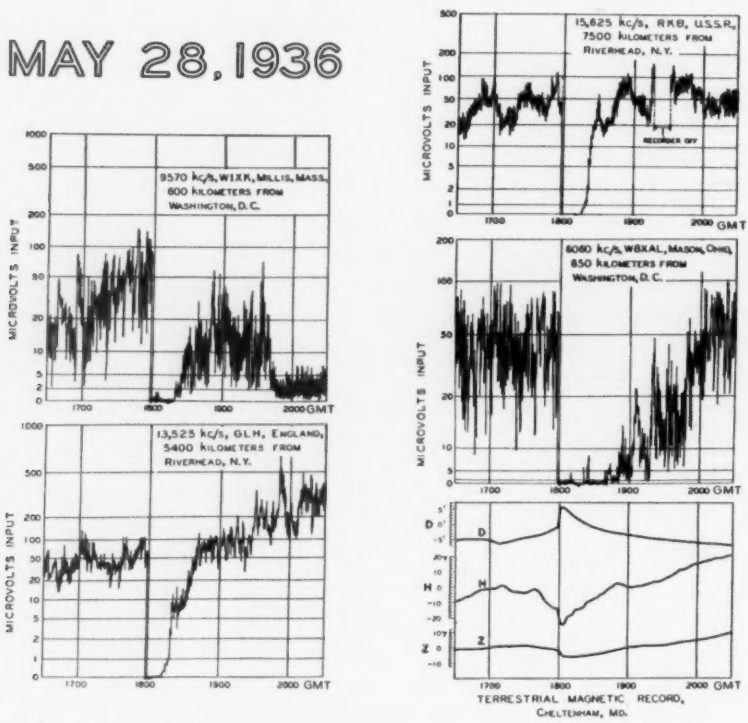
This sudden type of disturbance is the most startling of all ionosphere irregularities. Besides the magnetic and earth-current effects it also causes radio fadeouts, i.e., the sudden and complete disappearance of radio signals received on high frequencies. This phenomenon first came to my attention in 1935. Several radio stations reported to me a radio fadeout which occurred on May 12 of that year. As the reports accumulated, I was much interested to observe that at all these stations, although separated thousands of miles, the time the fadeout began was within four minutes of the same at all of them. This was true of other similar occurrences, and I soon had the further thrill of perceiving that the effect always occurred in the daytime, never at night, but occurred all over the side of the earth toward the sun. Formulating the hypothesis that the effect was due to some ionosphere change produced simultaneously throughout the illuminated hemisphere by some specific burst of radiation from the sun, I requested the astronomers at Mt. Wilson Observatory to examine their solar records at these times to see whether anything unusual had been observed on the sun at these times. They did so, and found that an unusual bright eruption had been observed on the sun at each of these times insofar as solar observations had been made.

I subsequently learned that the simultaneous occurrence of radio fadeouts at different places had been observed by T. L. Eckersley of England and H. Mögel of Germany in 1928. There was however no knowledge of their simultaneity with visible bursts of radiation from the sun until 1935.

The effect is very sudden, the diminution of the radio

signals to zero usually occurring within a minute. The whole effect lasts from about ten minutes to an hour or more. The effects are most intense in that region of the earth where the sun's radiation is perpendicular, i.e., greater at noon than at other times of day and greater in equatorial than in higher latitudes.

FIG. 14.



Radio and magnetic effects of a sudden ionosphere disturbance.

The effect is most striking. Sometimes all "static" as well as the radio signals disappear. Many a radio operator has taken his radio receiver apart, thinking that some wire had become disconnected, and on many of these occasions it has been thought that a fuse had been blown in the station.

Figure 14 gives an example showing both radio and magnetic effects. The four records of received field intensity from

distant stations show that the radio intensity suddenly dropped from normal intensity to zero at 1758 G. M. T., i.e., 12:58 P.M., Eastern Standard Time. This completely wiped out radio transmission throughout the hemisphere; reports to that effect were received from many points in the United States, also Europe and Japan. As shown, the effect lasted much longer on 6060 kc./s. than at the higher frequency, 9570 kc./s., at about the same distance. Note the occurrence of a fluctuation in the earth's magnetism at exactly the same time as the radio fadeout.

The cause of these effects is the sudden production, by a burst of ionizing radiation from an eruption in the sun's chromosphere, of a sudden and great increase in the ionization of a portion of the ionosphere below the *E* layer. This causes abnormally great absorption of radio waves passing through this ionized region on their way up to and down from the regular reflecting layers. The ionization of the normal reflecting layers is not affected. It is not known at just what height the abnormal ionization is produced, but it is probably in the *D* layer, a layer responsible for daytime skywave broadcast transmission, its height being from 50 to 90 kilometers at different times.

The reason this abnormal ionization is produced low in the ionosphere and not in the regular reflecting layers (*E*, *F*, F_1, F_2) is doubtless because the solar eruptions emit some radiations of different frequencies from those of the relatively steady radiations which maintain the ionization of the *E* and higher layers. This abnormal radiation is of such frequencies as to pass readily through the *E* and higher layers and be absorbed farther down, possibly by the ozone which exists at heights from about 20 to 60 kilometers. The frequencies of this radiation are presumably in the ultraviolet but nearer to the optical frequencies than those which maintain the regular ionization of the *E* and higher layers.

Study of these effects is arousing great interest and focusing new effort upon the study of the sun. The ultraviolet radiations which maintain the regular ionization of the ionosphere layers, while steady in comparison with those causing ionosphere disturbances, nevertheless fluctuate, as has been shown, in an 11-year cycle. They are probably associated

with the turbulent processes, or what might be thought of as innumerable minor eruptions in the sun, involved in the birth and life of sunspots. Neither the regular nor the irregular radiations from the sun which produce the effects in the ionosphere can be detected by laboratory means, because they are wholly absorbed in the ionosphere and do not reach the earth's surface.

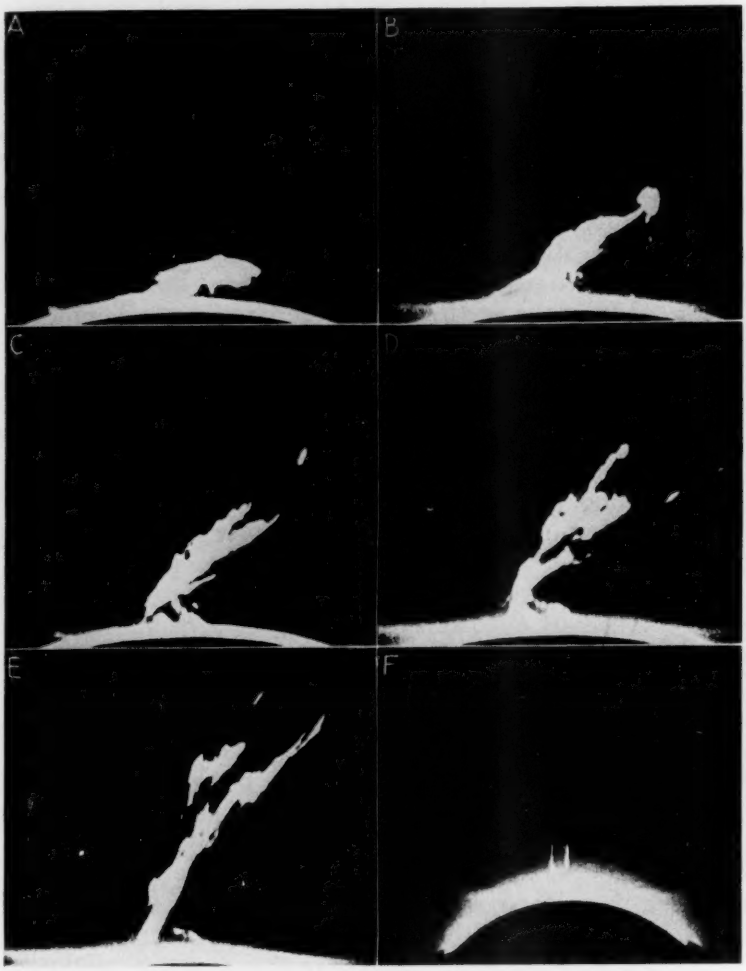
The sudden ionosphere disturbance is the only known instance in which a specific happening on the earth follows directly from a specific random happening on the sun or other heavenly body. Major solar eruptions can be studied particularly well by the aid of the sudden ionosphere disturbances which they cause. Study of these disturbances, and also of the more regular phenomena of the ionosphere, may eventually elucidate the nature of the eruptive processes within the sun and the causes of sunspots and the 11-year cycle.

The sudden ionosphere disturbances and the solar eruptions which cause them are more frequent during years of high sunspot numbers. The solar eruptions produce the effect regardless of location on the sun's surface. These eruptions usually, but not always, take place near an active sunspot group. Most of the eruptions which produce sudden disturbances of the ionosphere are much brighter than the average eruption.

A solar eruption may be seen in either of two ways, either as a sudden brightening and fading of an area on the sun's surface, or as a spurt of flame like a small eruptive prominence when it occurs at the edge of the sun's disc. An unusually great eruptive prominence is illustrated in Fig. 15. This was photographed by R. R. McMath on Sept. 17, 1937. It reached a height of 1,000,000 kilometers (620,000 miles). The speed of the action was enormous, as seen from the times given for the successive photographs. The speed of rise of material from the sun's surface reached 700 kilometers (430 miles) per second.

It is surprising that this extraordinary phenomenon was not linked with a particular type of magnetic disturbance or any other terrestrial phenomenon long ago. A few times during the past 80 years scientists have observed magnetic fluctuations occurring at the time of a solar eruption but these

FIG. 15.



Eruptive prominence on the sun (photograph by courtesy of R. R. McMath). Sept. 17, 1937, G. M. T.: A 1451, B 1456, C 1506, D 1509, E 1515, F 1606.

fluctuations were not identified as anything different from the irregular fluctuations which occur constantly. That a particular type of magnetic and ionosphere disturbance, caused by a solar eruption, has now been identified and segregated

from other types of disturbance, has moved the Carnegie Institution to state that "the way has been opened to the solution of many long recognized problems in the seemingly unrelated fields of solar astronomy, radio transmission, and terrestrial magnetism."

We have now examined the testimony of radio to the composition and properties of the earth's atmosphere, and have seen how these studies are contributing to knowledge of the sun. It remains to inquire whether radio can tell us anything else about the universe exterior to this earth. This inquiry is in two parts: can we learn anything by sending radio waves out from the earth, and are there radio effects produced by anything which comes to the earth from sources other than the sun?

It would be easy to send radio waves out from the earth if desired. We do it in fact; for ionosphere conditions favorable to the passage of radio waves into outer space are in existence all the time. Any frequency greater than the highest reflectable frequency of the highest layer (F or F_2) of the ionosphere penetrates and passes through the ionosphere.

Perhaps the simplest experiment to learn something from radio waves sent out from the earth would be an attempt to reflect them back from the nearest heavenly body, the moon. The distance of the moon, 384,000 kilometers (240,000 miles), is such that the echo would have a delay of two and a half seconds. It is not known whether the central part of the moon's disc has sufficient reflecting power for radio frequencies. An attempt to receive such echoes would presumably utilize a very powerful transmitter, large directive transmitting and receiving antenna systems pointed at the moon, a frequency somewhat greater than the maximum usable frequency for the angles of incidence at the highest ionosphere layer of either the transmitted or received waves, and a receiving location and time of minimum interference from atmospheric and man-made electrical disturbances. The experiment might be done in either of two ways: (*a*) have a large number of widely separated receiving locations with many coöperating observers, so as to increase the probability of receiving some of the weak reflected waves, or (*b*) use the same antenna system for both transmission and reception,

preferably at a location and time where the moon is at the zenith and limiting frequency a minimum. It is possible that conditions might be more favorable for reception of such echoes from the moon at the time of sunspot minimum rather than maximum, because of fewer absorbing ionized particles in the path of the waves. No moon echoes have ever been received.

Strangely enough, however, radio signal echoes have been received of such a length as to indicate reflection from something at distances even greater than the moon. These echoes are rare and rather mysterious. Their mode of production is unknown but it seems probable that they are reflected by concentrations in space of ions which came from the sun. The existence of ion concentrations capable of this is more likely during times of sunspot maximum than sunspot minimum, because of the greater and more sporadic ejection from the sun of many sorts of electrical particles during sunspot maximum. This expectation is fulfilled by the meager facts, in that the long-delay echoes were first discovered in 1927, the last sunspot maximum; they disappeared after about a year, and none were observed again until 1938, when a single case was reported to me. The longest time ever observed in one of these echoes was four and a third minutes. This indicated the reflecting medium to be at a distance of about 40,000,000 kilometers (25,000,000 miles), which is a hundred times the distance from the earth to the moon, and about a quarter of the distance from the earth to the sun.

It appears there would be no difficulty in transmitting radio waves to other planets (particularly Mars, Venus, or Mercury), nor in receiving radio waves if any should be sent from other planets. The conditions favoring success would be about as just stated for the moon experiment. Perhaps the chief difficulty would be estimating with sufficient accuracy the frequencies which would just penetrate the atmosphere of the other planet. If the frequencies used were less than the critical frequency of the planet's ionosphere they would not penetrate it. If they were too far above the critical frequency it is unlikely that the inhabitants of the planet would have developed suitable equipment for long-distance reception on such frequencies, since such frequencies would not be usable

for long-distance radio communication between two points on the planet.

The other question, whether radio effects are produced by anything which reaches the earth from sources other than the sun can be answered in the affirmative. Several types of messengers from space have spoken to us through radio effects. So far as I know, cosmic rays are not among them. The scientists of the Bartol Research Foundation and other organizations have been on the lookout for radio effects of cosmic rays, and I believe have found none.

One radio effect from outer space manifests itself as an anomalous type of atmospheric disturbances ("static") heard at very high radio frequencies. Careful investigation has shown that it always comes from a fixed general direction in space, the principal origin being in approximately the center of the Milky Way; i.e., the galaxy in which the sun is a star. This "static" may very well be caused by some emanations from the stars of our galaxy.

An experimenter is now making an investigation with a special 2-dimensional directive antenna system to determine whether there is an increase of such "static" when it is pointed at a hot giant star, and I understand there are some indications of positive effects.

That the stars produce effects observable in radio experiments is postulated by another scientist in explaining certain weak scattered radio reflections from the ionosphere, observed particularly at frequencies greater than those normally receivable from the regular layers. Those reflections are believed to be due to small ephemeral patches or "clouds" of ionization, and the suggestion is that these evanescent ion clouds are due to brief ionizing emanations from the stars. No investigation has yet been made to determine whether these stellar radiations, presumably of ultraviolet frequency, are directly accompanied by radiations producing the radio-frequency "static" from stellar sources just mentioned.

It is perhaps not too much to expect effects of this kind from the stars, in view of what we are learning about the sun. The sun is a star, and an average sort, though a small one. All the stars are glowing, seething furnaces, and on many of them doubtless occur vast cataclysms like the eruptions on the

sun. We had no way of learning about them until these radio effects appeared. It is quite possible that detailed study of the eruptions on the sun, which is relatively near us, will eventually tell us a great deal about events in the distant stars.

One astronomer has gone so far as to surmise that in the coming years radio apparatus will prove as effective a tool in astronomical research as the telescope has been in the past. This view is extreme. Certainly however we are no longer restricted to that narrow part of the electromagnetic spectrum which is visible light, in our exploration of the outer universe. Light occupies one octave of the spectrum. It was to be expected that the radio portion of the spectrum, occupying 18 octaves, would sooner or later be adapted to such exploration. We now have, for this purpose of probing the outer universe, besides visible light and radio, cosmic rays and ultraviolet radiation. To these we should perhaps add meteors. There are basically just two tools for the job, electromagnetic waves and particles. It is significant that these two tools by which we probe the infinite are the very same ones by which we probe the infinitesimal. We penetrate the atom by bombardment by particles and electromagnetic waves.

It is of further interest that the outer universe of the galaxies is about as far removed from us in magnitude in one direction as the inner or subatomic universe is in the other direction. Add that the same laws govern in the astronomical and the subatomic realm. Considering that modern physics is finding particles and waves to be but two aspects of the same thing, and that this thing seems to be the key to the outer and the inner universes, we see a new basis for faith in that eventual synthesis of truth which the great scientific spirits have foreseen. I know of no finer expression of this faith than is given by the poet,[1] whose vision ranges the universe and beholds our galaxy as a mere feather of light, the sun as just a spark, and the earth as a grain of dust.

"We, who are borne on one dark grain of dust
Around one indistinguishable spark
Of star-mist, lost in one lost feather of light,

[1] Alfred Noyes in "Watchers of the Sky."

Can by the strength of our own thought, ascend
Through universe after universe; trace their growth
Through boundless time, their glory, their decay;
And, on the invisible road of law, more firm
Than granite, range through all their length and breadth,
Their height and depth, past, present and to come.
So, those who follow the great Workmaster's law
From small things up to great, may one day learn
The entire structure of the heavens."

"In the time to come, perhaps a hundred years,
Perhaps a thousand, when our own names
Are quite forgotten, and our kingdoms dust;
On one sure certain day, the torch-bearers
Will, at some point of contact, see a light
Moving upon this chaos. Though our eyes
Be shut for ever in an iron sleep,
Their eyes shall see the kingdom of the law,
Our undiscovered cosmos. They shall see it,—
A new creation rising from the deep,
Beautiful, whole.
    We are like men that hear
Disjointed notes of some supernal choir.
Year after year, we patiently record
All we can gather. In that far-off time,
A people that we have not known shall hear them,
Moving like music to a single end."

GEIGER–COUNTER MEASUREMENTS OF THE VERTICAL COSMIC–RAY INTENSITY BETWEEN SEA–LEVEL AND 24,000 FEET.[1]

BY

W. F. G. SWANN AND W. E. DANFORTH,

Bartol Research Foundation of The Franklin Institute, Swarthmore, Pennsylvania.

BARTOL RESEARCH FOUNDATION
Communication No. 98.

Introduction. The investigation here reported was undertaken primarily with the object of refining our knowledge of the variation of cosmic-ray intensity with altitude in the more or less immediate vicinity of the earth, and with the intensity measured by counters as distinct from ionization chambers. It has been customary to divide the intensity roughly into two components, a hard component and a soft component. The relative magnitudes of these components play important parts in testing theories concerned with sea-level cosmic-ray asymmetry measurements, latitude variations, variations of latitude effect with altitude, and the like. If the intensity were accurately represented throughout the whole range of the atmosphere, by two exponential contributions, we could determine the relative amounts of such contributions and their absorption coefficients through observations over any or all ranges of the atmosphere. However, the analysis into two exponential contributions is only approximate, and is probably less representative of a pure fact of nature than is the existence of two distinct components of the radiation, of different physical nature, neither of which obeys necessarily a true exponential law. For this reason, when one desires the relative magnitudes of the components for the discussion of theories of phenomena near the earth's surface, it is better to obtain those components and their characteristics by the

[1] The data in this paper were obtained in the winter of 1936–37 and have been quoted on several occasions by the writers. For various reasons concerned with the discussion of their interpretation, and the more immediate pressure of other matters, the full publication of the work has been postponed until the present time.

analysis of data obtained relatively near to the surface than from data extending over the whole range of the atmosphere. A second purpose of these measurements was to extend to sea-level the observations obtained with our apparatus on the recent stratosphere flights.[2]

EXPERIMENTAL PROCEDURE.

The apparatus used was essentially that which we sent up into the stratosphere in the National Geographic U. S. Army Air Corps stratosphere flight made from South Dakota in November 1935. This apparatus has been described in sufficient detail elsewhere.[3] Through the kind coöperation of the late Major-General Oscar Westover, formerly head of the U. S. Army Air Corps, and Dr. Lyman J. Briggs, Director of the National Bureau of Standards, we secured the services of Captain H. K. Baisley to fly the apparatus at altitudes extending from sea-level up to 24,000 feet.[4] These flights were made from the Philadelphia Navy Yard through the courtesy of Commander W. W. Webster.

The apparatus provided the equivalent of twenty Geiger-counter telescopes all pointed simultaneously in a vertical direction so that, even in the limited periods possible in the single flights, we could obtain enough data to iron out the statistical fluctuations and secure satisfactory results.

A picture of the counter telescope apparatus is shown in Fig. 1. Its main axis lies horizontally instead of being vertical, as was the case in the stratosphere flight; and the ten boxes marked *A*, contain the ten pairs of Geiger-counter telescopes all of which, as already stated, were pointed in a vertical direction in the airplane flights. Only one of the methods of recording described in the former paper [2] was used. This method involved a mechanism in which each impulse resulting from the passage of a cosmic-ray through

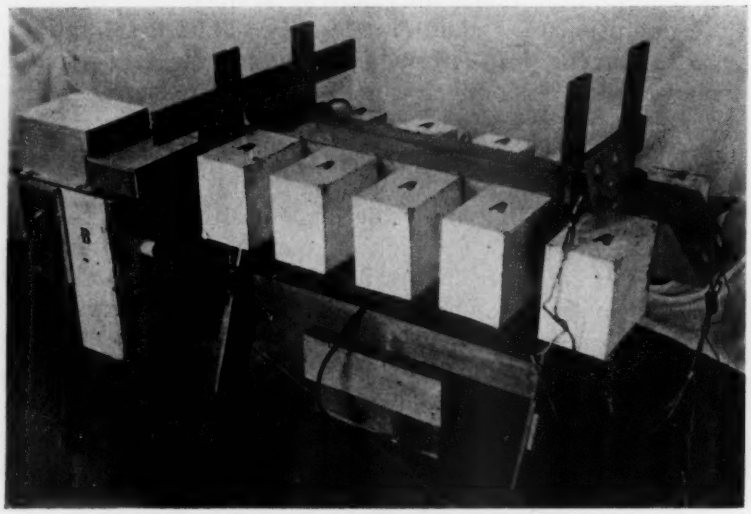
[2] W. F. G. Swann, G. L. Locher, and W. E. Danforth, *Phys. Rev.*, **51**, 389 (1937).

[3] W. F. G. Swann, G. L. Locher, and W. E. Danforth, Nat. Geog. Soc. Contributed Tech. Papers, Stratosphere Series, No. 2 (1936).

[4] It is a pleasure to acknowledge here the helpful cooperation extended by the Burgess Battery Co., who donated the dry cell batteries for this flight, and for former flights with this apparatus, into the stratosphere. We also wish to make similar acknowledgment to the R.C.A. Victor Company, who donated the vacuum tubes for these flights.

one of the telescopes imprinted a black line upon moving photographic paper. Ten vertical arrays of short black lines thus corresponded to the records of the ten pairs of telescopes contained in the ten boxes *A*, Fig. 1. Black dots were imprinted upon the record every fifteen minutes from a timing clock; and, in order that this clock mechanism should work satisfactorily it was found necessary to provide for it a heater in view of the rather severe temperature conditions encountered at the higher altitudes. The altitudes were

FIG. 1.



Apparatus used for the present airplane measurements. Each of the ten boxes marked *A* contains a pair of Geiger counter telescopes with vertical axis. Recording devices are contained in the unit *B* at the rear. With the main column mounted vertically, instead of horizontally, as here shown, this equipment was used for cosmic-ray measurements in the National Geographic Society U. S. Army Air Corps stratosphere flight of November, 1935.

obtained from the airplane altimeter which was known to be accurate to about 1 per cent.

Details of Counter Telescopes and Corrections. While it is unnecessary to describe the whole apparatus in detail, it will be helpful to counter specialists to have certain details on the counters themselves and their assembly into telescopes, so that the reliability of the final data may be gauged.

Each of the twenty counter telescopes comprised a triple

coincidence set of three units. Each of the units comprised three elements, in the form of individual counters connected in parallel. The three counter elements of each unit were staggered in triangular form in the usual manner, to provide as nearly as possible for a homogeneously sensitive area for each of the units. The distance between the equivalent planes of the outer units of a telescope was 9 cms. Each individual counter element was 3 cms. long and 1 cm. in diameter, these dimensions referring, of course, to the metal cylindrical part. Thus, the sensitive area of each unit was a little less than 9 square centimeters.

It is well known that two corrections must be considered in the operation of a counter telescope. The first of these depends upon the time T for which a counter element remains insensitive after experiencing a discharge. It depends also upon the intensity of the rays which are being recorded. The time T was determined as 0.0035 second, by oscillograph methods. The correction introduced by the finiteness of this time was quite negligible for the highest altitudes of the airplane flight. Even for the highest counting rates obtained in our former *stratosphere* flights it amounted to only about 7 per cent. In the data here quoted from those stratosphere flights the correction is made. The total counting rate of an individual counter necessary to calculate it was obtained in two different ways. The first way involved obtaining the rate from the actual observations themselves, making use of those at all zenith angles for the purpose of integrating over a complete hemisphere. The second way involved using the actual counting rates found by E. Regener and G. Pfotzer [5] for an individual counter at the altitudes concerned, allowance being, of course, made for the difference between sizes of Pfotzer's counter and ours. The former method gave a correction of 7 per cent. for the highest counting rates in the stratosphere, and the latter gave 4 per cent. We have taken 7 per cent. as more specifically applicable to our own observations. The relatively small correction here involved, as compared with those of most former observers, is inherent in the small size of the individual counter elements; and, it was to secure smallness of this correction that the counter elements

[5] E. Regener and G. Pfotzer, *Phys. Zeits.*, **35**, 779 (1934).

were designed of the small size stated for the first National Geographic U. S. Army Air Corps stratosphere flight.[6]

The second correction referred to depends upon the intensity of the radiation, the geometry of the system, and the resolving time of the electrical circuits involved. Again on account of the short resolving time (7×10^{-5} sec.) and on account of the design of the system, the correction concerned amounts in our case to only 1 per cent. for the highest counting rates obtained in the stratosphere. This is much smaller than the corrections found necessary by other recent observers.

RESULTS AND DISCUSSION.

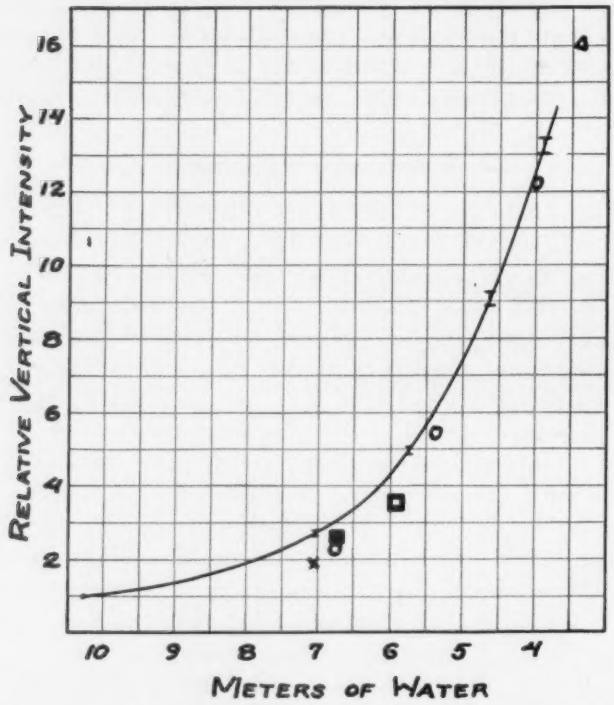
In Fig. 2 the curve represents our airplane observations at sea-level, 10,000 feet, 15,000 feet, 20,000 feet, and 24,000 feet, the short vertical lines associated with each point representing in the usual manner, the statistical uncertainties. The other plotted points represent, as specified in the caption, the data of other observers in this range of altitudes. The intensities given are relative and are reduced to the value unity at sea-level for all of the observations concerned.

It is of interest to see how our airplane measurements correlate with the observations made on the last National Geographic U. S. Army Air Corps stratosphere flight. In Fig. 3 the black dots represent the airplane observations including the sea-level observation. The crosses represent our results obtained on the aforesaid stratosphere flight. It may be remarked that the main object in the stratosphere flight was to obtain observations at the highest altitudes. The original plan to secure observations at various stationary altitudes had to be abandoned on account of the exigencies of the situation resulting from the aeronautical operations in connection with the flight. Other than for the summit, it was, therefore, only possible to secure observations during the rapid descent of the balloon, so that the statistical accuracy of these results is naturally limited by this circumstance. Moreover, observations were secured only down

[6] W. F. G. Swann and G. L. Locher, JOUR. FRANK. INST., **221**, 275 (1936). W. F. G. Swann, JOUR. FRANK. INST., **222**, 23 (1936). W. F. G. Swann, JOUR. FRANK. INST., **222**, 669 (1936).

to about 15,000 feet, where the batteries were thrown out as ballast. In spite of these facts, the results obtained by averaging over finite ranges of altitude during the descent, and represented by the crosses in Fig. 3, fit very well with

FIG. 2.



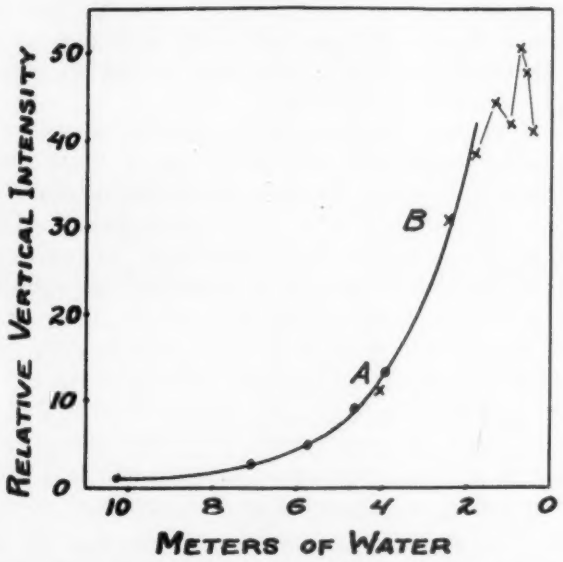
Altitude variation of counter-determined cosmic-ray intensity in the vertical direction as reported by several observers. Ordinates represent intensity at the altitude concerned divided by intensity at sea-level. Abscissae represent distances below the top of the homogeneous water equivalent atmosphere. Solid curve, with marks denoting measured values and associated probable errors, represents the authors' airplane data. Measurements of other workers are plotted as follows: Solid square, mountain data of T. H. Johnson (*Phys. Rev.*, **48**, 287 (1935)); cross, R. H. Woodward and J. C. Street (*Phys. Rev.*, 49, 198A (1936)); triangle, H. J. Braddick and C. W. Gilbert (*Proc. Roy. Soc.*, 156A, 570 (1936)); circles, G. Pfotzer (*Zeits. f. Phys.*, 102 (1–2), 23 (1936)); open square, C. D. Anderson and S. H. Neddermeyer (*Phys. Rev.*, **50**, 263 (1936)).

the airplane observations, and in a manner which will be more explicitly evident from what follows. Suppose that we should assign an intensity law of the form

$$I = A_1 e^{-\mu_1 x} + A_2 e^{-\mu_2 x},$$

where μ_1 and μ_2 are the two absorption coefficients, x the distance, in meters, below the top of the homogeneous water equivalent atmosphere, and A_1 and A_2 the corresponding intensity coefficients. Then, if the airplane observations were infinitely accurate, it would be possible to determine μ_1, μ_2, A_1, A_2, unambiguously from observations at four altitudes. However, the pitfalls inherent in attempts to determine

FIG. 3.



Altitude variation of counter-determined cosmic-ray intensity in the vertical, showing concordance of authors' airplane data (dots) with the manned-balloon data of W. F. G. Swann, G. L. Locher and W. E. Danforth (crosses). Ordinates and abscissae have the same meanings as in Fig. 2. Solid-curve is calculated on the basis of a two-component exponential analysis with absorption coefficients 0.58 and 0.00 per meter of water. The degree of ambiguity of such analysis is illustrated by the fact that coefficients 0.7 and 0.2 will give substantially as good agreement as the above, provided that the relative intensities of the two components are appropriately readjusted.

exponential coefficients and intensity coefficients unambiguously in this way from observational data are well known. Very small uncertainties in the observational data permit large variations in the coefficients.[7] Thus, in spite of the very satisfactory accuracy of the airplane data, the observa-

[7] W. F. G. Swann, JOUR. FRANK. INST., **209**, 151 (1930). L. D. Weld, *Phys. Rev.*, **40**, 713 (1932).

tions not only for four points, but for the five points at which measurements were actually taken, were fitted, within the limits of accuracy of the experiments, equally well by the assignments

$$\mu_1 = 0.58; \quad \mu_2 = 0.00; \quad A_1 = 1.57; \quad A_2 = 0.0088$$

and

$$\mu_1 = 0.70; \quad \mu_2 = 0.20; \quad A_1 = 2.04; \quad A_2 = 0.088.$$

As a matter of fact, the curve obtained with either of these sets of constants, when extrapolated even to the altitude corresponding to 2.4 meters of water, agrees satisfactorily with the observation obtained for that point on the stratosphere flight already referred to.

Figure 3 shows, between 10.3 meters of water depth (approximately sea-level) and the Point A (3.91 meters of water depth), the curve obtained from the airplane flights, by use of the values $\mu_1 = 0.58$; $\mu_2 = 0.00$; $A_1 = 1.57$; $A_2 = 0.0088$, these values being obtained to correspond to the five observational points represented by black dots. The portion of this curve to the right of the black dots is an extrapolation calculated on the basis of the foregoing constants. It will be observed that the airplane curve so extrapolated passes almost through the point B obtained in the stratosphere flight as corresponding to 2.4 meters of water. In fact, B falls off the curve by an amount which is within the limits of accuracy of observation. Moreover, even if the coefficients $\mu_1 = 0.70$; $\mu_2 = 0.20$; $A_1 = 2.04$; $A_2 = 0.088$ were used, the airplane curve with its extrapolation would be judged to be as good a fit to the experimental points as is shown by the curve in Fig. 3. The departure of the observation from the extrapolated curve at the highest altitudes is, of course, only to be expected, and is bound up with considerations concerned with the effect of limitation of the atmosphere upon secondary production.

In view of the foregoing considerations it will be clear that, even with high accuracy in the experimental data, it is impracticable to determine those coefficients with any satisfactory degree of definiteness. If, however, from other considerations, we fix any one of the four magnitudes concerned, our data serve to determine the others unambiguously.

If, indeed, we could fix the ratio of the sea-level intensities of the two components, the story would become unambiguously determined on the assumption, of course, of the existence of two absorption coefficients. Within the last two or three years we have come to admit the existence of at least two kinds of particles in cosmic-ray phenomena—electrons and mesotrons. The recent data of S. H. Neddermeyer and C. D. Anderson [8] determine the ratio of the number of mesotrons to electrons at sea-level, this ratio, for approximately vertical rays, being 38/17. If, using this ratio, we should associate the mesotron with the hard component and the electron with the soft component, our airplane results yield

$$\mu_1 = 0.59; \quad \mu_2 = 0.02; \quad A_1 = 1.64; \quad A_2 = 0.010.$$

However, tempting as this procedure may seem, it becomes vitiated in principle by the fact, recently brought to light, to the effect that the hard component rays are accompanied by electrons which have originated from them by secondary processes,[9] and which, being in equilibrium with their parents, masquerade with an apparent absorption coefficient equal to that of the parents. The percentage of the electrons which are of this type is cited as 93 per cent. in the theoretical calculations of L. W. Nordheim [10] with the reservation that the figure is probably too high. From experiments in a mine, and from experiments indoors at sea-level, W. E. Ramsey and one of the writers arrived at the conclusion that the penetrating rays were accompanied to the extent of something certainly more than 60 per cent. by electrons. Until the range of uncertainty in the number of electrons accompanying a mesotron is removed we are, therefore, unable to improve materially upon the wide range of uncertainty in the knowledge of the relative proportions of the two components and of their absorption coefficients intensity-altitude data alone, at least if we confine our information to counter measurements.

[8] S. H. Neddermeyer and C. D. Anderson, *Phys. Rev.*, **51**, 884 (1937).

[9] W. F. G. Swann and W. E. Ramsey, *Phys. Rev.*, **54**, 229 (1938); presented at Meeting of Ameri. Phil. Soc., No. 26, 1937. Also, W. F. G. Swann, JOUR. FRANK. INST., **226**, 441 (1938); also W. M. Nielsen, JOUR. FRANK. INST., **226**, 601 (1938); also V. C. Wilson, *Phys. Rev.*, **53**, 337 (1938).

[10] L. W. Nordheim, JOUR. FRANK. INST., **226**, 575 (1938).

Comparison of Geiger Counter Data with Ionization Chamber Measurements. The comparison of ionization data with observations from counters has for long been a subject of interest to students of cosmic radiation, and the analysis of the radiation into two components (not necessarily exponential) is still regarded by many as an instructive process. The object of this section is to appraise the two-component concept as regards its capacity to harmonize the altitude variation of counter and ionization measurements, taking due account of such known quantities as (1) the ionization per cc. per second at sea-level, (2) the total number of (counter-measured) particles at sea-level, (3) the ionization per cm. of path of a high energy particle. Before proceeding further, it might be well to review briefly the simple mathematical considerations involved.

Suppose that the number of rays dN at the zenith angle θ falling, per second, within the limits of the solid angle $d\omega$ is

$$dN = I_\theta d\omega da.$$

Then, considering a cylindrical channel of cross section da and length l cut through a volume V in the direction defined by θ, the ionization produced in the cylinder by the rays falling within $d\omega$ is $I_\theta d\omega l da$, and the total number of ions produced per second within the volume V by rays falling within the limits specified by $d\omega$ is

$$\Delta N_i = I_\theta \sigma d\omega \int l da = I_\theta \sigma V d\omega,$$

where σ is the ionization per centimeter of path. The total ionization produced per second in the vessel is, therefore,

$$N_i = V \int \sigma I_\theta d\omega. \qquad (1)$$

On the other hand, the total number of rays passing through the volume within the limits $d\omega$ is

$$\Delta N_c = I_\theta A_\theta d\omega,$$

where A is the area of that cross section of the volume which is perpendicular to the axis of $d\omega$. The total number of rays

passing through the volume is

$$N_c = \int I_\theta A_\theta d\omega. \tag{2}$$

The presence of A_θ under the integral for N_c complicates the relationship between N_i and N_c. If the volume is a sphere, so that A_θ is independent of θ we should expect N_i to be proportional to N_c under all conditions so long as σ is also a constant. On the other hand, even with σ constant, and with a non-spherical surface, the values of N_i and N_c at different altitudes would only be proportional to each other so long as I_θ was the same function of θ for all altitudes; in other words, so long as the dependence upon altitude was represented by a factor varying with altitude but independent of θ.

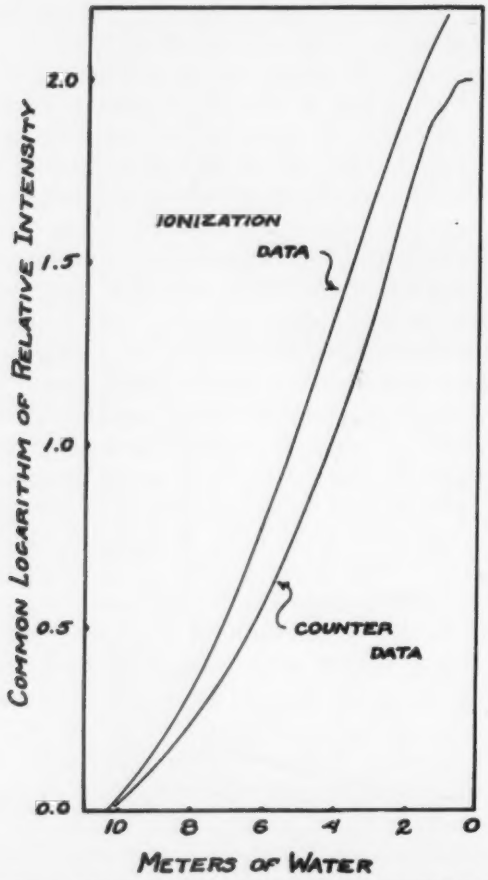
E. Regener and G. Pfotzer,[5] using a counter which presented approximately the same effective cross sectional area from all aspects, found an experimental proportionality between their data for N_c as obtained with a counter and N_i as obtained with an ionization chamber, the observations extending up to altitudes corresponding to a depth of 42 centimeters of water in the homogeneous atmosphere. Proceeding in a different manner, these investigators have deduced, from the ionization data, what the variation with altitude of the vertical intensity as measured by counters should be on the assumption that I_θ is a function only of $h \sec \theta$, where h is the distance from the top of the homogeneous atmosphere. By this procedure they have predicted a variation with altitude of the counter-measured intensity which agrees with the experimental data. This result is surprising in view of the fact that, as our zenith angle observations in stratosphere flights have shown,[2] the counter-determined intensity cannot be expressed as a function of $h \sec \theta$ for altitudes greater than 2 meters of water. Moreover, the conclusion is not substantiated by a similar procedure applied to more recent observations.

In comparing our own counter data comprising those from the recent airplane flights and those from our stratosphere flights with the ionization chamber data obtained at comparable latitudes by I. S. Bowen, R. A. Millikan, and H. V. Neher,[11] in the Fordney-Settle flight, we find a good agreement

[11] I. S. Bowen, R. A. Millikan and H. V. Neher, *Phys. Rev.*, **46**, 641 (1934).

at higher altitudes; but in making this comparison we have used our own former data upon the variation of intensity with zenith angle at high altitudes. Had we used an angular variation based upon the $h \sec \theta$ law, the harmony between the ionization and counter data at high altitudes would have been completely destroyed. Figure 4 gives the comparison

FIG. 4.



Altitude variation of ionization in a thin-walled chamber compared with that of counter measurements which have been suitably integrated over all zenith angles. Ordinates represent the common logarithm of the ratio of a datum at the altitude concerned to that at sea-level. If each entity recorded as a count produced the same average ionization at all altitudes, the curves would coincide. The divergence of the curves at sea-level and their approximate parallelism (i.e. constant ratio) at high altitudes demand, of course, the presence of more than one component, and suggest the dominance at high altitudes of a single, more highly ionizing, component. The ionization data presented is that of I. S. Bowen, R. A. Millikan, and H. V. Neher, obtained from the Fordney-Settle flight.

between our counter data and the ionization data of the Fordney-Settle flight. The ordinates are logarithms of the calculated and observed ionizations referred to sea-level as unity. It is the *parallelism* of these curves which is really symbolic of the actual harmony of the results for high altitudes. We may assume that this harmony prevails only where the soft component of the radiation dominates; and that the lack of harmony at lower altitudes, which is represented by the divergence of the curves in those regions, is attributable to the existence of two components of comparable importance as regards intensity in these regions. It will be interesting at this stage to elaborate in greater detail upon the apparent discrepancy between the counter and ionization data at low and intermediate altitudes, and to discuss the possible significance of this apparent discrepancy. In this connection it must be remarked that R. A. Millikan has recently expressed lack of confidence in the results of the Fordney-Settle flight on account of the fact that subsequent data obtained with pilot balloons have been in disagreement with the results of that flight. As the disagreement is attributable to the gondola housing the apparatus, and since our own Geiger counter measurements were made in a similar gondola, there is perhaps better basis for comparison of our results with those of the Fordney-Settle flight, than for their comparison with those obtained with pilot balloons.

We revert once more to Fig. 2 for the counter data and observe that these data show a wide discrepancy among themselves, a discrepancy which is of the same order of magnitude as the discrepancy between counter data and the ionization chamber data. Nevertheless, the general consistency of our airplane observations with the stratosphere data tempts us to make the present discussion in terms of these airplane and balloon data exclusively. For altitudes up to that corresponding to 4 meters of water, the angular integration is accomplished by invoking the $h \sec \theta$ law. At higher altitudes, where this law is no longer valid, we have available our actual measurements of distribution in zenith angle.

Let us suppose that the cosmic-rays comprise two components, different as regards their apparent absorbability, and

different also in their power to produce ionization in a closed vessel. It will turn out to be convenient to regard one of these components—the hard component—as composed of mesotrons, while the other component—the soft component—is to be regarded as purely of electron type. A penetrating ray and an electron ray will affect a counter equally; but the latter, through shower production in the wall of a vessel which it enters, will result in an amount of ionization different from that produced by the electron ray.

We shall denote by ρ the true ionization per centimeter of path by an individual ray of any character. ρ_s shall express the value which we should have to use in place of ρ to take care of any showers produced by the soft component rays in passing through the walls of the ionization chamber, and ρ_h shall express the corresponding quantity for the hard component rays, so that in this case ρ_h represents an average for the two types (electrons and penetrating rays) of which the hard component rays are composed.

Following the line of discussion already given, it is easy to see that if $\rho_s = \rho_h = \rho'$, the rate of production of ions in a vessel, as calculated from the flux of cosmic-rays through it, would be of the form

$$N_c = \rho' f_s(h) + \rho' f_h(h), \tag{3}$$

where $f_s(h)$ and $f_h(h)$ are functions of the altitude h characteristic of the soft and hard components. The quantity N_c is typical of the quantity cited as obtained from counter data in Fig. 4. On the other hand, for the case where ρ_s and ρ_h are different (3) becomes replaced by

$$N_i = \rho_s f_s(h) + \rho_h f_h(h). \tag{4}$$

From (3) and (4) it appears that if the addition of a zero subscript implies a value determined at sea-level, then $(N_i/N_{io})/(N_c/N_{co})$ attains at infinite altitude a limit L given by

$$L = \operatorname*{Lim}_{f_s(h) \to \infty} \frac{\rho_s f_s(h) + \rho_h f_h(h)}{\rho_s f_s(o) + \rho_h f_h(o)} \Big/ \frac{f_s(h) + f_h(h)}{f_s(o) + f_h(o)}$$

$$= (1 + \alpha)/(1 + \alpha/\epsilon), \tag{5}$$

where $\alpha = f_h(o)/f_s(o)$; $\epsilon = \rho_s/\rho_h$. Hence

$$\epsilon = L\alpha/(1 + \alpha - L). \tag{6}$$

Again, following the hypothesis that the radiation can be divided into two components, we have as the number of rays per cm.^{2} per second integrated over all values of zenith angle at sea-level,

$$\int I_{o\theta} d\omega = f_s(o) + f_h(o).$$

The ionization per cc. per second will be

$$\frac{N_{io}}{V} = \rho_s f_s(o) + \rho_h f_h(o),$$

writing $\rho_h = \beta\rho$, so that $\rho_s = \epsilon\beta\rho$, we have

$$\frac{N_{io}}{V} = \rho[\epsilon\beta f_s(o) + \beta f_h(o)],$$

which, written in terms of α, becomes

$$\frac{N_{io}}{V} = \rho\beta[f_s(o) + f_h(o)]\frac{\alpha}{1 + \alpha - L}. \tag{7}$$

From (6) and (7) we can obtain at once the quantity $\epsilon\beta$. Thus, writing $f_s(o) + f_h(o) \equiv J_o$, we have

$$\epsilon\beta = \frac{N_{io}}{\rho V}\frac{L}{J_o}. \tag{8}$$

Our analysis so far has really been independent of a detailed specification of the nature of the hard and soft components. If, as a matter of definition, we should take the hard and soft components to correspond to what the empirical analysis of the altitude data brings forth in terms of two absorption coefficients; we should, in the light of our more recent knowledge, be compelled to regard the so-defined hard component as a mixture of mesotrons and electrons which have arisen from the mesotrons by shower production in the atmosphere. With this interpretation of $f_h(h)$ in relation to $f_s(h)$, we should have to regard ρ_h as a properly defined average between the true specific ionization applicable to the mesotrons

and the value $\epsilon\rho$ applicable to the electrons. The simplest procedure is to regard $f_h(h)$ as applying to the mesotrons and $f_s(h)$ as applying to the electrons—regardless of their origin. In this we sacrifice what is a matter of small consequence—a perpetuation of the attempt at association of the true absorption coefficients with the measured absorption coefficients, as obtained from the exponential analysis.

Now the formulæ we have deduced above provide us with certain inescapable conclusions.

Thus, (7) gives

$$\beta = \left(\frac{N_{io}}{V\rho J_o}\right)\frac{(1 + \alpha - L)}{\alpha}. \tag{9}$$

The value $J_o = [f_s(o) + f_h(o)] = 0.025$ has been obtained by J. C. Street and R. H. Woodward.[12] R. A. Millikan [13] has obtained the value 2.48 for (N_{io}/V). Using these in conjunction with the normal value $\rho = 33$ ions per cm. of path obtained by W. F. G. Swann and W. E. Ramsey,[14] we obtain, from (9),

$$\beta = 3\frac{(1 + \alpha - L)}{\alpha}. \tag{10}$$

If the mesotrons were present in superabundant proportion at sea-level, we should have $\alpha = \infty$, which would necessitate $\beta = 3$. On the other hand, if we seek the conditions necessary to permit $\beta = 1$, which would correspond to the case of mesotrons functioning as individual entities without multiplication and producing normal ionization, we shall require $\alpha = 3(L - 1)/2$. The value of L corresponding to Fig. 4 is $L = 2$, which would give $\alpha = 3/2$. This is in rough agreement with the value $38/17 = 2.12$ quoted from Neddermeyer and Anderson [8] as the ratio of the number of mesotrons to electrons at sea-level. However, it is probable that the value 2.12, referring as it does to certain limited ranges of energy and direction, is too low as a representative of the comparison for all the rays; and it is probable that α may be as high as 3.

[12] J. C. Street and R. H. Woodward, *Phys. Rev.*, **46**, 1029 (1934).

[13] R. A. Millikan, *Phys. Rev.*, **39**, 397 (1932).

[14] T. H. Johnson, "Cosmic-Ray Intensity and Geomagnetic Effects," *Rev. Mod. Phys.*, **10**, 193 (1938), (see p. 211).

With $L = 2$, this would require $\beta = 2$, and with a smaller value of L a larger value of β would be necessitated.

Turning now to (6), we can readily show that ϵ increases with L for all permissible values of α and L. Moreover, for a given L, the smallest of all possible values of ϵ is that for the case $\alpha = \infty$, in which case $\epsilon = L$. In other words, $\epsilon = L$ is the smallest of all possible values of ϵ. For $\alpha = 3$ and $L = 2$, we should have $\epsilon = 3$.

The quantity ϵ is representative of the difference between the characteristics of the mesotrons and electrons as regards the multiplicative feature in the walls of the ionization chamber.[15] Only for the case $L = 1$ does equation (6) permit as small a value of ϵ as unity and so equality of characteristics of electrons and mesotrons in this matter.

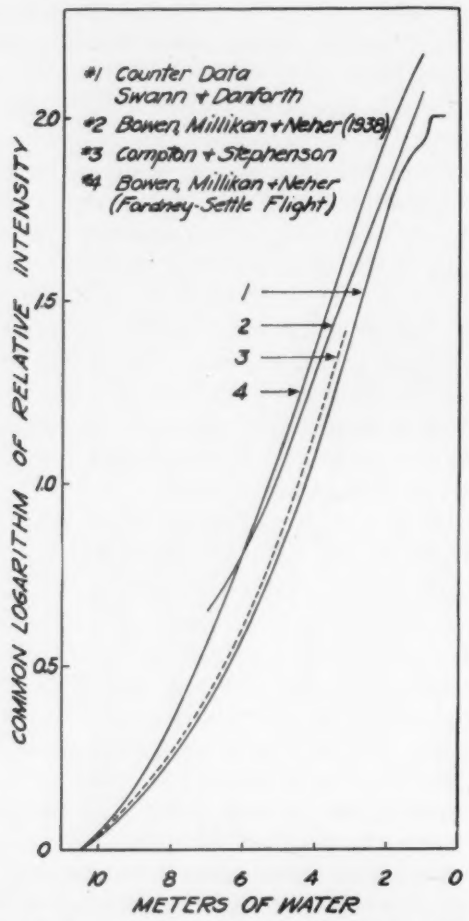
It will be recalled that $\beta\epsilon$, and not ϵ is the total multiplicative factor for the electrons. While our formulæ for both β and ϵ depend upon α, the expression (8) for $\beta\epsilon$ involves only L; and with the data already quoted for (N_{io}/V), J_o, and ρ, comes out as $\beta\epsilon = 6$, which is of course in agreement, as it must be, with the product of $\beta = 2$, and $\epsilon = 3$, calculated above for the particular case $\alpha = 3$.

Equation (8) shows in the most direct manner that the multiplying factor for the electron rays is bound up completely with L. If there were no electrons, the "counter curve" and the "ionization chamber curve," Fig. 4, should coincide. It is interesting to observe that if we include ionization chamber data for the case where the chamber was shielded with lead, the quantity L approximates more to unity, as we should expect, on account of the partial elimination of the electrons rays which, on the above views, are solely responsible for any difference between L and unity. Thus, Fig. 5 shows Fig. 4 with the ionization chamber data of A. H. Compton and E. C. Stevenson, taken also on the Fordney-Settle flight, but with the chamber shielded with 6 cms. of lead, added. It will be observed that these observations lie very close to those of our counter curve. Figure 5 also shows the data given by I. S.

[15] The ordinary quantum theory of pair formation is quite inadequate to provide for $\epsilon = 3$ in the case of an iron vessel 1/8 inch thick such as was used by Millikan and his collaborators on the Fordney-Settle flight.

Bowen, R. A. Millikan, and H. V. Neher [16] for unshielded apparatus in a pilot balloon flight from Nebraska. They are plotted for a sea-level ionization of 2.48 ions/sec./cc./atmos-

FIG. 5.



Curves similar to Fig. 4, but with results of various other ionization chamber measurements, as indicated.

phere. Apart from some abnormalities in comparison with the other data for the lower altitudes, these data give a curve

[16] I. S. Bowen, R. A. Millikan, and H. V. Neher, *Phys. Rev.*, **53**, 855 (1938).

which at high altitudes (but below the maximum) runs approximately parallel to our counter data; and while the departure from the counter curve is less than that for the Fordney-Settle flight, it is of the same order of magnitude, giving $L = 1.8$ instead of 2.

It is true that the ionization chamber curves in Figs. 4 and 5 depend upon the value 2.48 taken for the sea-level ionization. However, in so far as there is a departure from this value in the case of other observers, the departure is in the direction of a smaller value, which would enhance the difference between the counter data and the ionization chamber data. Swann's data,[17] taken in an iron vessel one inch thick, yielded 1.98 ions/sec./cc./atmosphere, when unshielded by lead, and 1.16 when shielded by 2 inches of lead.

It is interesting to observe that even if there were no departure between the ionization chamber curves and the counter curves, so that $L = 1$ and $\epsilon = 1$, we should still be left with the necessity of assuming, in accordance with (8), that $\beta\epsilon$, and so $\beta = N_{io}/\rho J_o = 3$. In this case, both the electron rays and the mesotrons would call for a multiplying factor of 3. This factor is large out of all proportion to anything which the straight application of the quantum theory of multiplicative showers can provide for.

[17] W. F. G. Swann, JOUR. FRANK. INST., **209**, 151 (1930).

Pittsburgh Award.—Announcement has been made that the annual award of the Pittsburgh Section of the American Chemical Society will be made to GEORGE HUBBARD CLAPP. The award, an aluminum plaque suitably inscribed, is made in recognition of outstanding service to chemistry in the Pittsburgh District. Notable achievements in the field of chemistry attended Mr. Clapp's work with Capt. Hunt and Charles Martin Hall in the production of aluminum by an inexpensive electrolytic process. Notable also were his activities in the pioneer Pittsburgh Testing Laboratory, which provided technical service to the growing steel industry and which, through its experimental filtration plant led to the building of Pittsburgh's present filtration plant and the attendant enormous reduction of typhoid in Pittsburgh; as first president of the Scientific Materials Co. (now the Fisher Scientific Company); and his interest in scientific research at the University of Pittsburgh and at the Carnegie Museum.

R. H. O.

Big Du Pont Building being Air-conditioned.—Air-conditioning of the du Pont Building in Wilmington, Del., was begun recently. It is one of the largest of the kind yet undertaken in the U. S. It comprises almost 400,000 square feet of floor space and will provide all-season temperature and humidity control for the entire block-square 13 story structure excepting the ground floor, theater and hotel. The hotel's main dining rooms and a large part of the ground floor of the office building are already air-conditioned. The theater is closed in summer. Refrigerating equipment with a total capacity of 1200 tons will be located in the basement. Cold water will be conveyed to 42 multi-unit conditioners. Ducts located in corridors and concealed by false ceilings will carry the conditioned air to offices. Present awnings and window shades are to be replaced with Venetian blinds. A country-wide study of air-conditioned buildings was made by the du Pont company before deciding on the project. Experimental installations were made in parts of the du Pont Building. Conditions in the company's air-conditioned Nemours Building, completed in 1937, were especially observed. The evidence was overwhelming in favor of all season air-conditioning. Testimony was that working efficiency is increased, there is less fatigue at the end of the day, and that susceptibility to colds is greatly reduced. The first section of the du Pont Building was erected in 1907. It was not until 1931 that the final section closed the square the building now occupies in Wilmington's business center.

R. H. O.

THE EARTH'S ELECTRIC FIELD AND THE AURORÆ.

BY

M. C. HOLMES, Sc.D.,

Department of Physics, West Virginia University.

This is the third of a series of three papers on the subject of the earth's electric field. The first, published in April 1937,[1] dealt with the possibilities resulting from the external electric field that would exist as a consequence of a non-uniform distribution of electric charge over the earth. It put forward the idea that cosmic rays are electrified particles accelerated by such a field. Since that time it has been adjudged that cosmic rays are a local phenomenon and that the most recent evidence does not show that the earth is moving appreciably with respect to the source of the rays.[2]

The second paper of the series [3] was concerned with the resonance effects produced by the combination of the earth's electric field acting on the polar water molecules of the atmosphere and wireless waves. It was shown that the resonance frequencies would lie in the region of short wireless waves and could therefore account for the anomalous reflection and absorption of such waves. In particular it reconciled the observed fact of reflection from low levels in the atmosphere with the failure of balloon ascension measurements to detect any physical discontinuity such as an ionized layer at those heights.

The present paper is concerned with a study of the possible relationship between the electric field of the earth and the auroræ. One of the most comprehensive set of measurements of the electric gradient is that made aboard the Carnegie.[4]

[1] "A Terrestrial Origin for Cosmic Rays," Holmes, M. C., JOUR. FRANK. INST., **223**, No. 4, p. 495, Apr. 1937.

[2] See *Science*, **88**, No. 2292, p. 10, Dec. 2, 1938, a report presented by Compton and Gill at the Chicago meeting of the Am. Phys. Soc.

[3] "Polar Molecules in the Earth's Electric Field as Absorbers of Wireless Waves," Holmes, M. C., JOUR. FRANK. INST., **225**, No. 3, p. 309, Mar. 1938.

[4] See the Carnegie Ocean Magnetic and Electric Observations 1915–21, Researches, Dept. of Terr. Mag., Carnegie Inst., Washington D. C., 1926.

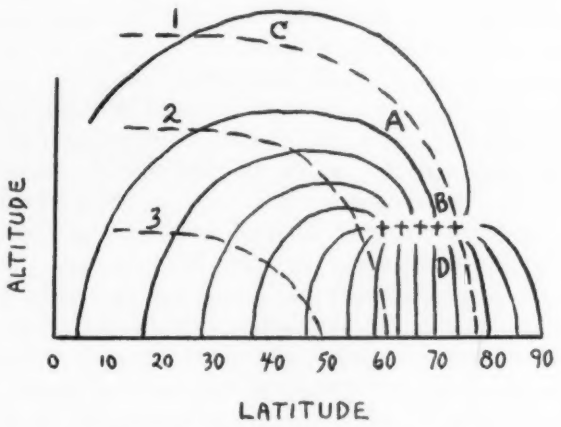
There the following facts were established: first, a variation of the electric field with sunspot cycle; second, a variation of electric field strength with universal time; third, a variation of field strength with latitude. The field strength, on the average, was lowest in the equatorial regions and increased gradually as higher latitudes were reached.

This increase of field strength with latitude is the most important fact from the standpoint of the present study. The fact that the earth has an electric field, with potential increasing with altitude, predicates an accumulation of positive charge in the upper atmosphere. The increase with latitude implies an even more dense accumulation of positive electricity toward the polar regions. If the charge had been uniformly distributed over the earth, then as a result of Gauss' law, there could be no external field above the charged layer, on the assumption of a neutral earth. Conversely, since the charge is not uniformly distributed we must conclude that there exists an electric field above the charged region. This state of affairs can be analyzed in the simpler language of Faraday by reference to Fig. 1. There the increased concentration of positive charge above the polar region is represented by the pluses. The effect of the remaining, uniformly distributed portion, not indicated in the figure, would be to superimpose a uniform field below the region of charge.

The full lines represent the direction of the electric field and the dotted lines indicate the general direction of the earth's magnetic field. Nothing is said as to the probable height of this region of positive charge, whether 10 kilometers or 1000 kilometers, but attention is directed to the fact that there will be an electric field above as well as below the charged region, also that at certain places the electric lines will be parallel with the magnetic lines while at other places the two sets of lines will be perpendicular to each other. The next factor is that electrified particles, or ions, which are everywhere present in the earth's atmosphere, will experience forces tending to accelerate them along the lines of electric force. When the ions attain sufficient speeds, they are capable of causing ionization by collision with neutral molecules, with the subsequent emission of light, a phenomenon so familiar at present in neon signs. Two factors exist,

however, tending to modify such processes. First, the crossing of magnetic lines which will cause the ions to move in cycloidal and spiral paths[5] depending upon the angle between the electric and magnetic lines and the initial velocities and masses of the ions. This means that ionization by collision will be prevented in regions below and to the left of some magnetic line such as 2 in Fig. 1. Second, in the lower regions of the atmosphere where the molecular density is great and the mean free paths of the ions between collisions too short to allow the requisite speeds to be attained, ionization will also

FIG. 1.



Distribution of electric charges and lines of force.

be prevented. For example, a field strength of about 30,000 volts per centimeter is required for ionization at sea level, whereas only about 1.5 volts per centimeter exists normally. This precludes the possibility of ionization along the lower portion of the dotted line 1 (below D), leaving only a narrow region (A) extending from the point C where the electric and magnetic lines begin to be parallel, down to some point B or D where the air density is still sufficiently low to permit ionization by the existing electric field. At this point then we propose the theory that the aurora represents ionization by

[5] The equations for these motions have been derived by L. Page, see "The Motions of Ions in Constant Fields," *Phys. Rev.*, **33**, 553, 1929.

the earth's electric field in this limited region. The supporting evidence follows.

1. FORMS AND MOVEMENT OF THE AURORÆ.

There are many serious objections to theories of the aurora based upon corpuscular rays shot out from the sun. If negative particles are postulated the radius of the auroral zone is too small. Auroral bows, which remain stationary for many hours at a time are difficult to account for. Probably the most serious objection to the solar origin theory rests upon the fact that the beams of charged corpuscles required by the theory would dissolve by electrostatic repulsion long before reaching the earth.[6] The electric field theory presented above, however, is able to account for both the forms of the auroral arcs, draperies and streamers, and also for their erratic movements. In this theory ionization takes place in the region A whenever the electric field reaches a high enough value and whenever the magnetic and electric lines become parallel. The stationary auroral arcs or bows would correspond to steady values of the two fields. The rapid movement of the ray structure is accounted for by changes in direction of either the magnetic or electric fields throwing the two into and out of parallelism. The characteristic lateral movements would be produced automatically by the collapse of the electric field at a region of intense ionization, with the ionization passing on to neighboring regions that had not yet discharged. The peculiar and intricate forms and movements become readily understandable on this theory as evidence of changing regions of parallelism and changing electric field strengths.

2. THE CLEARLY DEFINED LOWER BOUNDARIES OF AURORAL CURTAINS.

The lower limits of the auroræ are usually quite sharp and distinct. The distribution curves of these heights usually show two clearly defined maxima, or modes, one at a height of 100 kilometers, the other at 106 kilometers. Based on our theory this lower limit represents the critical height below

[6] For a summary of facts regarding auroræ see "A Summary of the Facts and Theories of the Auroræ," Hewston, E. W., *Rev. Mod. Phys.*, **9**, No. 4, p. 403, Oct. 1937.

which the mean free paths of the molecules are too short to permit ionization by collision. It may be interesting to pause here and calculate the field strength needed to cause ionization at a height of 100 kilometers. The average field required for ionization at sea level is customarily taken as 30,000 volts per centimeter. Now the pressure at a height of 100 kilometers is not known with any very great degree of accuracy but is about 8.8×10^{-6} times the pressure at sea level according to the tables by Humphreys, and about $.36 \times 10^{-6}$ according to the calculations of Chapman and Milne. If it requires 30,000 volts per centimeter at sea level then it would require $3 \times 10^{6} \times 8.8 \times 10^{-6}$, or 26 volts per meter, for ionization at 100 kilometers according to Humphreys and about 1.1 volts per meter according to Chapman and Milne. This at least gives some idea of the field needed to cause ionization at these heights. At 106 kilometers, of course, it would not need to be so large. Roughly we can say that it needs to be only about 1/100 as large as that known to exist at sea level.

It is well known that for each kind of gas a definite value of ionizing potential exists. The values are approximately 15.5 volts for oxygen, 16.9 volts for nitrogen and 25.2 volts for helium. Discordant results are reported for hydrogen but most experiments place its value above nitrogen and below helium (see for example "Electricity in Gases," by Townsend, table on page 358). This means that as the electric field increases, oxygen will ionize first, then nitrogen, then hydrogen and finally helium. Or if the field is constant, it means that oxygen will ionize at the lowest levels, nitrogen at the next higher, hydrogen next and finally, at the highest levels, helium. The two modes at 100 kilometers and 106 kilometers may thus be due to the two different ionizing potentials of oxygen and nitrogen for example. Again, the strength of the field itself at any given point will tend to be limited by the ionization potential of the most easily ionized gas present. This may be the explanation for the fact that the strong green line (5577.6) of metastable oxygen is almost always present in the spectra of the auroræ, also the positive and negative bands of nitrogen, but that the lines of hydrogen and helium are either not present or extremely weak.

3. CORRELATION WITH SOLAR ACTIVITY.

Theories of a solar origin, with rays of electrified particles shot out from the sun perhaps were suggested by the correlation between the sun's activity and the occurrence of auroræ. It is well known, however, that changes in the earth's magnetic field also exhibits correlation with solar activity. The magnetic and electrical fields both exhibit diurnal, annual and secular variations. Hence, since the aurora, according to our theory, depends upon parallelism of these two fields one would expect the auroral phenomena to show similar correlations. It is not at all necessary to postulate rays actually coming from the sun itself.

SUMMARY.

The theory presented here is the result of logical deductions from a single fact, that of the variation of electric gradient with latitude. For the gradient to increase with latitude a charge distribution with lines of force somewhat as pictured in Fig. 1 must exist. Then, if the electric field has a strength of only about 1/100 that at sea level, ionization will take place wherever the electric and magnetic fields are parallel. The causes of the auroræ, their locations, their complex forms and movements, correlation with solar activity, diurnal and secular periodicities, all follow.

LE CONSERVATOIRE NATIONAL DES ARTS ET MÉTIERS, PARIS.

BY

H. PHILIP SPRATT,

London.

This ancient institution comprises what is said to have been the first technical museum in the world, to have been realised or even contemplated. The ecclesiastical premises which it occupies date back to 1060, and consist in fact of the church and cloisters of Saint-Martin-des-Champs which was founded under Henri I. The notorious Cardinal Richelieu was one of its titular priors. At the time of the French Revolution, these premises were allocated to an educational institution under the direction of Léonard Bourdon, and were later used for the manufacture of small arms. The pioneer movement for public technical education of the workers is attributed to Descartes, whose scheme included lecture rooms for all trades and handicrafts, with tools and machines for practical demonstration; such collections would at least approximate to our modern conception of a technical museum.

No practical commencement was made with the scheme until 1775, when Vaucanson started a small collection of tools and machines for demonstration purposes. There was also a similar collection which the *Académie des Sciences* had assembled at the Louvre, but which had never been opened to the public. On his death in 1782, Vaucanson bequeathed his collection of about 300 technical exhibits and "un nombre considérable de machines anciennes et nouvelles" to the state under Louis XVI, who in 1783 caused them to be opened to the public as the first industrial museum. Within a decade the inevitable need for expansion arose, and when the new *Conservatoire des Arts et Métiers* was established soon after the French Revolution, the museum which had developed from the Vaucanson collection was installed in the ancient premises of Saint-Martin-des-Champs, where it has remained ever since.

What can be termed the "Science Museum" of Paris is located near the Arts-et-Métiers station of the Métro, in one of the commercial quarters eastward of the Opéra and the Louvre, and is open free to the public on Sunday and Thursday afternoons; on all other afternoons, with the exception of Monday, there is a small entrance fee of 3 francs (about 10 cents). The main entrance in the rue Saint-Martin (Fig. 1) is flanked with statues of Science and Art, while a second modern portal is adorned with busts of eminent

FIG. 1.

Main entrance of the Conservatoire.

French scientists. From the street, there appeared to be more scope for "showmanship" to attract the casual public into the museum. When I visited the Conservatoire for the first time, some important subterranean extensions (which will be described later) were in hand, and the spacious forecourt (Cour d'Honneur) was filled with concrete mixers and heaps of sand. Behind these obstructions I found the broad stone staircase which leads to the main door of the museum.

In the vestibule are some fine specimens of French ceramics, and busts of famous (international) men of science. For example, there was Franklin, to the honour of whose

name the technical museum of Philadelphia is dedicated. This room is known as the *Salle de l'écho*, because words whispered in one corner are audible in the opposite one. The various halls, in three stories, comprise a total floor area of 8000 sq. metres (about 86,000 sq. feet) available for the exhibits, which at present number more than fifteen thousand. The first hall is devoted to mines and the extraction of metallic ores; there was a notable exhibit of pure nickel ore. In the

FIG. 2.

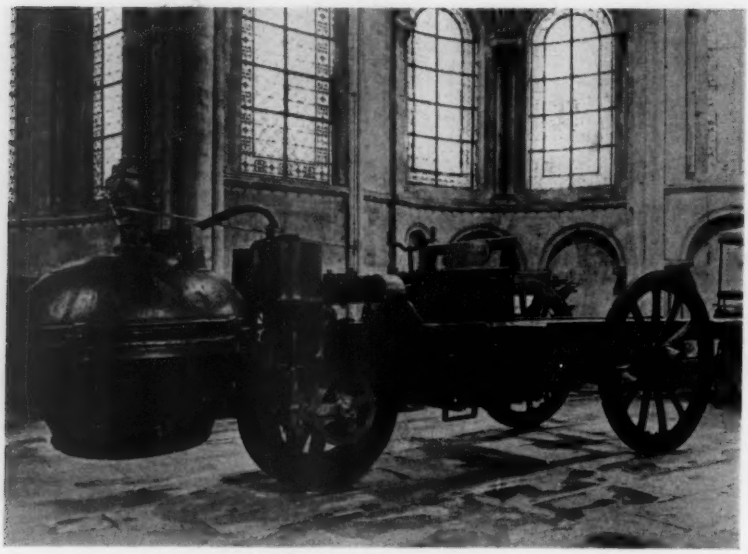
Statue of Liberty.

metal-work section, I noticed some modern examples of current practice in the use of aluminium for aeronautical construction, and a model of the aluminium sphere in which Piccard made his famous stratosphere ascents. There was also an effective exhibition of special stainless steels used for steam turbine blades, and some fine examples of artistic handwork in iron.

Next follows a small collection of timber specimens and woodwork, from which a corridor leads into the ancient church. The nave, with mullioned windows and wooden

roof, contains two pioneer steam-driven aeroplanes of Ader, and the historical machine in which Blériot crossed the Channel from Calais to Dover. There is also the authentic pendulum which Foucault used to demonstrate the rotation of the earth, and the model from which the Statue of Liberty, noble monument of democratic freedom, was constructed (Fig. 2). At the eastern end are statues of Gramme and Pascal. The apse contains a number of velocipedes, and the

FIG. 3.



Steam road vehicle (1770).

first steam road vehicle (Fig. 3) which is said to have attained a speed of 2000 *toises* (about two and a half miles) per hour. The boiler proved inadequate, however, and the machine was unable to run for more than about fifteen minutes, after which "il fallait ensuite la laisser reposer" to recover sufficient steam to continue. A scale model of this remarkable machine can be seen at the Science Museum in London.

In the corridor eastward from the church are collections of farm implements, after which follow exhibits on the prevention of accidents to workmen in various industries.

There are appliances for rescue work and first aid, and examples of defective boiler parts which would result in explosion. A further section deals with protective devices for saws, looms and other machines. On the northern side of the museum are five consecutive rooms with a corridor devoted to structural materials and public works. There are models of the famous Garabit viaduct, the shield used to drill the Mont Cenis tunnel, various cranes and other structural plant. Now follows the fine collection of mathematical and astronomical instruments. This includes a telescope of Newton, and a pair of binoculars made for Louis XVI. There are also theodolites and Borda circles, some ancient astrolabes, chronometers and musical clocks. In the department of measures are preserved the ancient reference metres of Lenoir and Fortin, also one of the modern international standard metres constructed in Paris.

The mechanical collections on the first floor are comprehensive in scope, and contain models of fine workmanship, some of which can be seen in motion on application to the attendant. There are models of windmills, the old form of Poncelet water-wheel for comparison with modern efficient water turbines, shown in section, also a small Pelton impulse wheel with the cover removed. Steam boilers and their accessories are well represented. There are two models (scale 1 : 10) of Watt machines, and others with Corliss valves. One of the earliest de Laval steam turbines ever constructed is also on exhibition, and the pioneer internal combustion machine of Lenoir. The development of rail transport is illustrated with an extensive collection, which includes models of three Stephenson locomotives. Other sectioned models (scale 1 : 10 for the most part) show details of modern French locomotives, for both steam and electric traction. There are also numerous exhibits of railroad material, some of them from Great Britain, and demonstration models of compressed air and vacuum brakes.

The marine section contains models of some representative paddle and screw steamers. The machines include those of the British warship "Northumberland" which are represented with a model (scale 1 : 12) from the builders. Another fine model (scale 1 : 10) shows the power unit of a Nile paddle

steamer. There are also models of marine boilers and their accessories, paddle-wheels and screw propellers. Now follow the collections of historical apparatus (such as that of Lavoisier) and models to demonstrate the fundamentals of science. For instance, the compression and liquifaction of air, the decomposition of water, the action of electrical machines and induction coils, various chemical properties and the utilisation of solar heat are all well represented. The acoustical section contains some fine old harpsichords and other musical instruments; the Ferdinand Berthoud collection of watches and clocks likewise includes some valuable specimens. There are also the first experimental telephones of the inventor Graham Bell, and exhibits to show the development of modern wireless communication.

Machine tools are represented with a comprehensive collection which includes an elaborate lathe built for Louis XVI in 1780, and the historical machine which Vaucanson invented for chain manufacture. Modern practice is shown with examples of automatic capstan lathes, and other machine tools for wood and metal work. The ceramics department contains some beautiful specimens of faience medallions, soft and hard porcelain and fine enamels; there is a Sèvres bowl with bas-reliefs of various arts and crafts which should be mentioned. Raw materials, tools and models of furnaces are also exhibited to show the methods of manufacture. The textile section is rich in superb examples of Gobelins, Beauvais and Aubusson tapestries. Some old Chinese and Indian looms were on exhibition, with models of other textile machines. There was also a collection of the war-time paper clothes which were manufactured and worn in France.

On the second floor are some additional rooms which accommodate the demonstration models on applied kinematics, and the reference collection of prints. The main library [1] of the Conservatoire is housed in the ancient *réfectoire* of Saint-Martin-des-Champs which now forms the *Salle de Lecture*, and which P. de la Force, in his *Description de Paris*, considers "est ce qui existe de plus parfait dans le Gothique." The hall measures about 150 feet, and is divided with seven

[1] Spratt (H. Philip), "Libraries for Scientific Research in Europe and America." 227 pp. with frontis. Grafton and Co., London, 1936.

central columns of remarkable boldness which support the vaulted roof (Fig. 4). The collections number at present more than 100,000 volumes on technical science (with some rare manuscripts of historical importance), while about 300 current technical periodicals are received. The tables which accommodate more than 100 readers are provided with indirect illumination.

The educational work of the Conservatoire includes at

FIG. 4.

Library of the Conservatoire.

present about 28 courses of lectures on various branches of pure and technical science, industrial art and commercial law. The attendance has necessitated the recent construction of two new lecture halls and considerable extensions to the experimental laboratories. That was a difficult proposition, because the Conservatoire has streets around three sides, and is built-up on the fourth; horizontal extension was impossible. To superimpose an additional floor would have marred the beautiful old architecture; there remained no choice but to delve downward. That is what has been done (Fig. 5), and

excavations to a depth of 18 metres (59 feet) under the *Cour d'Honneur* have now provided all the additional space needed. Careful provision had to be made for artificial ventilation and illumination; the latter was not considered a drawback, because all the lectures are held after dark. The main auditorium has 800 seats, while two others can each accommodate 250 persons. There is also the so-called "ancient amphitheatre" which still retains some of its old-fashioned charm.

FIG. 5.

Subterranean lecture hall.

Another educational service of importance has now been undertaken at the Conservatoire, in the production of scientific films to illustrate the public lectures. This new department has made, for example, some effective slow-motion pictures to elucidate the action of complicated mechanisms. Special exhibitions are held from time to time and, on a recent visit to the museum, I was invited to one of textiles. The historical development was traced down to the modern production of artificial silk, while a collection of

Gobelins tapestries formed an artistic feature. The ecclesiastical architecture of the Conservatoire, beautiful in itself, is not quite suitable for technical museum purposes; while some of the collections, of exceptional interest from both the historical and scientific points of view, are still exhibited in old-fashioned overcrowded cases, so that the casual visitor would perhaps not appreciate their true value. With all these minor defects, however, there is a cultured atmosphere about the Conservatoire, which retains much of that old-world charm so dear to the hearts of all who love France.

Intercrystalline Cracking in Boiler Plates.—In a paper before the North-east Coast Institution of Engineers and Shipbuilders recently C. H. DESCH referred to the type of cracking in steam boilers, characterized by the spreading of cracks in riveted seams between and around the rivets, which was shown by Parr and Straub to be associated with the use of alkaline water, either natural or rendered so by additions. Unlike cracks caused by fatigue or by corrosion, these cracks are intercrystalline. The attack only occurs where it is possible for the alkali to reach a high concentration in capillary spaces, and it is not observed in seamless drums. The literature of the subject is reviewed, and experiments conducted at the National Physical Laboratory are described, in which the possible factors were separately investigated, including prolonged and alternating stress, condition of steel, intermittent loading, and nature of solution. The explanation which had been proposed elsewhere that caustic soda alone was without effect, and that the attack only occurred in the presence of sodium silicate, has not been confirmed. Experimental methods are described, and the possible mechanism of the attack is discussed. Two parallel cases, of attack by caustic solutions in evaporating tanks, and attack by solutions of nitrates, in both of which intercrystalline cracking occurs in the absence of external stress, are also discussed.

R. H. O.

Windbreaks Slow Up Hot Winds On Plains.—Winds that threaten crops and erode and parch farm land in the Great Plains, this year find more than 7,000 miles of shelter belts in their path. These field windbreaks, a part of the Prairie States Forestry Project of the United States Forest Service, practically stop wind erosion. Probably more important, they reduce evaporation of moisture from the soil and from growing crops. Farm fields and crops, like laundry on the line, dry rapidly in a stiff wind. Because conditions vary, field windbreaks may be of different widths and run in different directions. Larger belts of 7 to 10 rows of trees a half mile apart may be supplemented by belts of 2 to 3 rows every quarter-mile. Shrubs or low growing trees along the edge of the larger shelter belts retard the wind from the ground up. A prevalent opinion has been that trees use more moisture than they are worth, but by comparison of adjoining fields—one field with windbreaks, one without—the Forest Service has shown that crops on tree-protected land will average higher than on the unprotected field.

R. H. O.

THERMAL INSTABILITY OF DIELECTRICS UNDER CONTINUOUS VOLTAGES WHEN THE CONDUCTIVITY IS DEPENDENT UPON THE FIELD STRENGTH.*

BY

ANDREW GEMANT, Ph.D., M.D.

1. INTRODUCTION.

The theory of thermal instability of dielectrics has been developed quantitatively among others by K. W. Wagner [1] and V. Fock.[2] Although extended later in several directions, by K. W. Wagner and A. Gemant,[3] for instance, with regard to the variation with frequency of the breakdown voltage, one point had not yet been discussed with greater detail, namely, the influence on the breakdown voltage of the variation with the fieldstrength of the electrical conductivity. Apart from an approximate treatment by W. Rogowski [4] there did not until recently exist a quantitative extension in this direction.

Considering the experimental material carried out by the British Electrical Research Association the author in collaboration with S. Whitehead had decided to attack this problem. The experimental work of S. Whitehead and W. Nethercot,[5] and L. Hartshorn and E. Rushton [6] has indicated the extent to which the electrical conductivity depends upon the field-strength, and stressed the importance of this fact with regard to thermal instability. This result seemed to be a sufficient warrant for a quantitative extension of the original theory.

The mathematical treatment is quite different, according as the voltage applied is D.C. or A.C. In the first case the field distribution is controlled by the real part of the con-

* Communication from the Department of Electrical Engineering, The University of Wisconsin, Madison.

[1] K. W. Wagner, *Journ. Am. Inst. El. Eng.*, **41**, 1034 (1922).

[2] V. Fock, *Arch. Elektrotechn.*, **19**, 71 (1927).

[3] K. W. Wagner and A. Gemant, "Berl. Akad. Ber.," 1934.

[4] W. Rogowski, *Arch. Elektrotechn.*, **13**, 153 (1924).

[5] S. Whitehead and W. Nethercot, *Proc. Phys. Soc.*, **47**, 974 (1935).

[6] L. Hartshorn and E. Rushton, *J.I.E.E. 83*, 315 (1938).

ductivity, in the second by a complex one. However, with A.C. at lower temperatures, up to say 100° C. the role of the dielectric loss will be negligible in this respect, and the field distribution governed chiefly by the dielectric constant. From temperatures of say 200° C. onwards, on the other hand, the role of the dielectric constant can be neglected, and the case can be treated exactly like D.C.

The "A.C." case (that is A.C. for lower temperatures) with the dielectric loss angle as a function of fieldstrength has been treated quantitatively by A. Gemant and S. Whitehead [7] as just mentioned. It has been shown that nearly any function of the fieldstrength can be dealt with with sufficient accuracy in that case.

The "D.C." case (i.e. D.C. for any temperatures, and A.C. for higher ones) will be discussed in this paper. The treatment, being more involved than the "A.C." case, does not, however, allow any function of the fieldstrength to be considered with any degree of accuracy. Accordingly only two special cases should be dealt with here, which appear to be important according to the experimental data. It has been shown by the authors quoted above that, although different conductivity functions seem to exist, a large part of the measurements can be reproduced by the following equation:

$$\sigma = \sigma_0(1 + bE)e^{at}, \qquad (1)$$

where σ = electrical conductivity in absolute units, E = fieldstrength in e.s.u., t = temperature in °C., and σ_0, b, a = constants.

The two special cases are the following:

(*a*) $bE \ll 1$. This case will hold chiefly for dielectrics of homogeneous structure, where b is small, or generally for thick specimens, in which the limiting voltage is approached, and E is fairly low. The term bE will be considered as a correction term to 1.

(*b*) $bE \gg 1$. This case holds for dielectrics containing voids, and generally for thin specimens in which E may reach fairly high values. Here the term 1 should be completely neglected as compared with bE.

[7] A. Gemant and S. Whitehead, Brit. El. Res. Assoc. Report 1937, and Phil. Mag. *27* (1939).

These two cases do not exhaust the different possibilities in actual arrangements, but they will occur quite frequently, and are representative for two main groups.

2. FIRST CASE: LINEAR TERM SMALL.

We write:

$$\sigma = \sigma_0 \left(1 + b \frac{d\varphi}{dz} \right) e^{at} \tag{1a}$$

with φ = potential, and z = direction parallel to field, the latter being taken as homogeneous. Now:

$$\sigma \frac{d\varphi}{dz} = j, \tag{2}$$

where j = constant, namely the current density. Putting (1) into (2):

$$\frac{d\varphi}{dz} = \frac{1}{2b} \left(-1 + \sqrt{1 + \frac{4jb}{\sigma_0} e^{-at}} \right),$$

and this into (1a):

$$\sigma = \frac{\sigma_0}{2} \left(1 + \sqrt{1 + \frac{4jb}{\sigma_0} e^{-at}} \right) e^{at}. \tag{3}$$

Further:

$$k \frac{dt}{dz} + j\varphi = 0 \tag{4}$$

(k = thermal conductivity of dielectric), since the flow of heat through any cross-section is equal to the heat produced between that plane and $z = 0$ (plane of symmetry). For the boundary: dielectric metal we have from (4):

$$j\varphi_b = \frac{t_b - t_0}{P}, \tag{5}$$

where φ_b = potential at boundary, t_b = temperature at boundary, t_0 = ambient temperature, P = external heat resistance (that of electrode and packing). Putting (5) into (3), we get:

$$\sigma = \frac{\sigma_0}{2} \left(1 + \sqrt{1 + \frac{4b(t_b - t_0)}{\sigma_0 P \varphi_b} e^{-at}} \right) e^{at}. \tag{6}$$

This equation for the conductivity has to be placed in the equations used by Fock. These are the following: Eliminating $j \cdot dz$ from (2) and (4), we obtain:

$$\varphi^2 = -2k \int_{t_m}^{t} \frac{dt}{\sigma} = u(t) - u(t_m) \tag{7}$$

by denoting the maximum temperature for $z = 0$ by t_m, and:

$$u(t) = -2k \int \frac{dt}{\sigma}. \tag{8}$$

Putting (7) into (4), we obtain, by integration:

$$jz = k \int_{t}^{t_m} \frac{dt}{\sqrt{u(t) - u(t_m)}}. \tag{9}$$

The boundary conditions give from (9):

$$jh = k \int_{t_b}^{t_m} \frac{dt}{\sqrt{u(t) - u(t_m)}} \tag{10}$$

with $2h$ = total separation of electrodes, and from (7):

$$-\varphi_b^2 + u(t_b) - u(t_m) = 0, \tag{11}$$

which together with (5) determine the equilibrium, being a system of three equations with three unknowns t_m, t_b and j for a given arrangement and potential. Eliminating j, one gets, with $c = h/kP$:

$$\int_{t_b}^{t_m} \frac{dt}{\sqrt{u(t) - u(t_m)}} - \frac{c(t_b - t_0)}{\varphi_b} = 0. \tag{12}$$

(11) and (12) represent the solution.

The breakdown voltage is obtained by constructing the Jacobian function from (11) and (12), and equating it to zero. Denoting (12) by F_1 and (11) by F_2:

$$\frac{\partial F_1}{\partial t_b} \cdot \frac{\partial F_2}{\partial t_m} - \frac{\partial F_1}{\partial t_m} \cdot \frac{\partial F_2}{\partial t_b} = 0. \tag{13}$$

In evaluating the four differentials, we have to bear in mind that $u(t)$ is a function not only of the integration limit, but according to (6) also of t_b due to its occurrence in σ. We shall

denote a differential of u with respect to its integral limit by u' and with respect to t_b occurring in σ as $\dot{u}$. Accordingly we have

$$\frac{\partial F_1}{\partial t_b} = -\frac{1}{\sqrt{u(t_b) - u(t_m)}} - \frac{c}{\varphi_b} - \frac{1}{2}\int_{t_b}^{t_m} \frac{[\dot{u}(t) - \dot{u}(t_m)]dt}{[u(t) - u(t_m)]^{3/2}}, \quad (14a)$$

$$\frac{\partial F_1}{\partial t_m} = \frac{1}{\sqrt{u(t_m) - u(t_m)}} + \frac{1}{2}\int_{t_b}^{t_m} \frac{u'(t_m)dt}{[u(t) - u(t_m)]^{3/2}}, \quad (14b)$$

$$\frac{\partial F_2}{\partial t_b} = u'(t_b) + [\dot{u}(t_b) - \dot{u}(t_m)], \quad (14c)$$

$$\frac{\partial F_2}{\partial t_m} = -u'(t_m). \quad (14d)$$

The difficulty with regard to the first term in (14b) being infinite is only apparent which becomes evident by partial integration of the second term:

$$\frac{1}{2}\int_{t_b}^{t_m} \frac{u'(t_m)dt}{[u(t) - u(t_m)]^{3/2}} = -\frac{1}{\sqrt{u(t_m) - u(t_m)}} + \frac{u'(t_m)}{u'(t_b)\sqrt{u(t_b) - u(t_m)}} - u'(t_m)\int_{t_b}^{t_m} \frac{u''(t)dt}{[u'(t)]^2\sqrt{u(t) - u(t_m)}}.$$

After having carried out a similar partial integration in (14a), (13) can easily be calculated, and the result will be:

$$\int_{t_b}^{t_m} \frac{u'(t)[\dot{u}(t)]' - u''(t)[\dot{u}(t) - \dot{u}(t_b) - u'(t_b)]}{[u'(t)]^2\sqrt{u(t) - u(t_m)}}dt + \frac{c}{\varphi_b} = 0. \quad (15)$$

In solving (11), (12) and (15), t_b, t_m and φ_b may be calculated, the latter being half the breakdown voltage. In carrying out the required integrations, the function u has to be specialized by substituting (6) into (8). In the following differentiations the second term in (1a) shall be considered small compared with the first, thus allowing to expand functions of the argument $b(d\varphi/dz)$ (or equivalent) to the

second term. Hence, from (6):

$$\sigma = \sigma_0 \left(1 + \frac{b(t_b - t_0)}{\sigma_0 P \varphi_b} e^{-at} \right) e^{at} \tag{16}$$

and from (8):

$$u(t) = \frac{2k}{a\sigma_0} e^{-at} - \frac{bk}{\sigma_0 P a \varphi_b} (t_b - t_0) e^{-2at}. \tag{17}$$

We now introduce with Fock a further simplified notation by writing

$$at = x, \tag{18}$$

$$\sqrt{\frac{a\sigma_0}{2k}}\, \varphi_b = v, \tag{19}$$

$$e^{x_b - x_m} = \cos^2 \Theta. \tag{20}$$

Then (11) takes the form:

$$e^{-x_b} \sin^2 \Theta - \gamma e^{-2x_b}(1 - \cos^4 \Theta) - v^2 = 0, \tag{21}$$

where

$$\gamma = \frac{b(x_b - x_0)}{2\sigma_0 P a \varphi_b}. \tag{22}$$

The integration of (12) yields, considering always the approximation used:

$$2\Theta \sec \Theta e^{x_b/2} + \gamma e^{-(x_b/2)}(\Theta \cos \Theta + \sin \Theta) - \frac{c}{v}(x_b - x_0) = 0. \tag{23}$$

As to (15), it can be separated into three different integrals, all of which having the variable $(x_m - x)$. One of them is solved by means of the integral

$$\int \frac{dy}{\sqrt{e^y - 1}} = 2 \arcsin \sqrt{1 - e^{-y}},$$

the other can be reduced to

$$\int \frac{e^y dy}{\sqrt{e^y - 1}} = 2\sqrt{e^y - 1},$$

and the third to

$$\int \frac{e^y dy}{\sqrt{e^{-y} - 1}} = -\arcsin \sqrt{1 - e^y} - e^{y/2}\sqrt{1 - e^y}.$$

We finally arrive to the equation:

$$e^{x_b/2}\sec^3\theta(\theta+\sin\theta\cos\theta)\times\left\{-1+\left(2-\frac{1}{x_b-x_0}-\frac{\cos^2\theta}{2}\right)\gamma e^{-x_b}\right\}-2\frac{\gamma}{x_b-x_0}\sin\theta e^{-x_b/2}-\gamma\frac{\theta}{\cos\theta}e^{-x_b/2}+\frac{c}{v}=0. \quad (24)$$

Eqs. (21), (23) and (24) are now used for final evaluation. We denote the correction terms containing γ by A, B and C. From (23):

$$A=\gamma e^{-x_b/2}(\theta\cos\theta+\sin\theta). \quad (25)$$

From (21):

$$B=\gamma e^{-2x_b}(1-\cos^4\theta) \quad (26)$$

and from (24)

$$C=\gamma e^{-x_b/2}\left[\sec^3\theta(\theta+\sin\theta\cos\theta)\times\left(2-\frac{1}{x_b-x_0}-\frac{\cos^2\theta}{2}\right)-\frac{2\sin\theta}{x_b-x_0}-\frac{\theta}{\cos\theta}\right]. \quad (27)$$

First x_b is eliminated; from (21) we have:

$$e^{-x_b/2}=\frac{v}{\sin\theta}\left(1-\frac{B}{2v^2}\right) \quad (28)$$

and this value is put into (23) and (24). The latter yields:

$$c=\sin\theta\sec^3\theta(\theta+\sin\theta\cos\theta)\left(1+\frac{B}{2v^2}\right)-Cv \quad (29)$$

or:

$$c\left[1-\frac{B}{2v^2}+\frac{Cv}{\sin\theta\sec^3\theta(\theta+\sin\theta\cos\theta)}\right]=\sin\theta\sec^3\theta(\theta+\sin\theta\cos\theta) \quad (30)$$

and the former:

$$\frac{2\theta\sec\theta\sin\theta}{v}\left(1+\frac{B}{2v^2}\right)-\frac{c}{v}\left(2\ln\frac{\sin\theta}{v}+\frac{B}{v^2}-x_0\right)+A=0. \quad (31)$$

Replacing c in (31) by (29), we obtain, after rearrangement, always keeping in mind the possible approximations:

$$v = e^{-x_0/2} \sin\theta e^{-(\theta\cos^2\theta)/(\theta+\sin\theta\cos\theta)} \times\left[1 - \frac{Av}{2\sin\theta\sec^3\theta(\theta+\sin\theta\cos\theta)} + \frac{B}{2v^2} - \frac{Cv\theta\cos^5\theta}{\sin\theta(\theta+\sin\theta\cos\theta)^2}\right]. \quad (32)$$

(30) and (32) represent the final solution.

3. SECOND CASE: LINEAR TERM LARGE.

If in Eq. 1 the second term is large compared with the first, the latter may be neglected and the conductivity written:

$$\sigma = \sigma_0 b \frac{d\varphi}{dz} e^{at}. \quad (33)$$

From (2) we obtain, as before:

$$\sigma = \sqrt{\sigma_0 b j} e^{at/2} \quad (34)$$

or (compare (6)):

$$\sigma = \sqrt{\frac{\sigma_0 b(t_b - t_0)}{P\varphi_b}} e^{at/2}. \quad (35)$$

We then have, instead of (17):

$$u(t) = \frac{4k}{a\sigma_0\sqrt{2\gamma}} e^{-x/2} \quad (36)$$

and the following derivatives:

$$u'(t) = -\frac{2k}{\sigma_0\sqrt{2\gamma}} e^{-x/2}, \quad (36a)$$

$$u''(t) = \frac{ak}{\sigma_0\sqrt{2\gamma}} e^{-x/2}, \quad (36b)$$

$$\dot{u}(t) = -\frac{2k}{\sigma_0(x_b - x_0)\sqrt{2\gamma}} e^{-x/2}, \quad (36c)$$

$$[\dot{u}(t)]' = \frac{ak}{\sigma_0(x_b - x_0)\sqrt{2\gamma}} e^{-x/2}. \quad (36d)$$

(11), (12) and (15) represent the solution, as before. (11) yields the equation:

$$\sqrt{\frac{2}{\gamma}}\sin^2\psi e^{-x_b/2} - v^2 = 0, \tag{37}$$

where, instead of (20), we use:

$$e^{x_b - x_m} = \cos^4\psi. \tag{38}$$

(12) gives, after integration:

$$2\sqrt{2}\psi \sec\psi \sqrt[4]{2\gamma e^{x_b}} - \frac{c}{v}(x_b - x_0) = 0 \tag{39}$$

and (15):

$$\frac{c}{v} - \frac{1}{\sqrt{2}}\left(\frac{1}{x_b - x_0} + 1\right) \times \sqrt[4]{2\gamma e^{x_b}} \sec^3\psi(\psi + \sin\psi\cos\psi) = 0. \tag{40}$$

From (37):

$$v\sqrt[4]{\gamma e^{x_b}} = \sqrt[4]{2}\sin\psi. \tag{41}$$

This, put into (39), gives:

$$4\psi\tan\psi = c(x_b - x_0) \tag{42}$$

and into (40):

$$c = \left(\frac{1}{x_b - x_0} + 1\right)\sin\psi\sec^3\psi(\psi + \sin\psi\cos\psi). \tag{43}$$

From (42) we deduce:

$$x_b = \frac{4\psi\tan\psi}{c} + x_0. \tag{44}$$

This, put into (43), gives:

$$c = \left(1 + \frac{c}{4\psi\tan\psi}\right)\sin\psi\sec^3\psi(\psi + \sin\psi\cos\psi). \tag{45}$$

And rearranging (41), we obtain:

$$v = \sqrt[3]{\frac{2\sin^4\psi}{\beta(x_b - x_0)}}\, e^{-x_b/3}, \tag{46}$$

in denoting:

$$\frac{\gamma v}{x_b - x_0} = \beta. \tag{47}$$

Eqs. (44), (45) and (46) represent the final solution.

For $c \ll 1$ (45) becomes:

$$c = 4\psi^2.$$

(44):

$$x_b = 1 + x_0$$

and (46):

$$v = \sqrt[3]{\frac{c^2}{8e\beta}}\, e^{-x_0/3}. \tag{48}$$

The breakdown voltage increases with the 2/3 power of the separation. This last equation is the same as deduced by S. Whitehead and W. Nethercot, l. c.

For $c \gg 1$, on the other hand, (45) becomes:

$$4\psi \cos^2 \psi = \psi + \sin \psi \cos \psi$$

with $\psi = 0.9$; (44):

$$x_b = \frac{4.54}{c} + x_0$$

and (46):

$$v = \sqrt[3]{\frac{c}{6.0\beta}}\, e^{-x_0/3}, \tag{49}$$

the voltage increasing with the third power of separation.

For intermediate thicknesses the general formulae have to be used.

4. NUMERICAL CALCULATIONS.

(*a*) For the first case the computation is approximative, i.e. we first neglect additional terms entirely and calculate v accordingly. With this solution the correction terms are computed and the value for v improved.

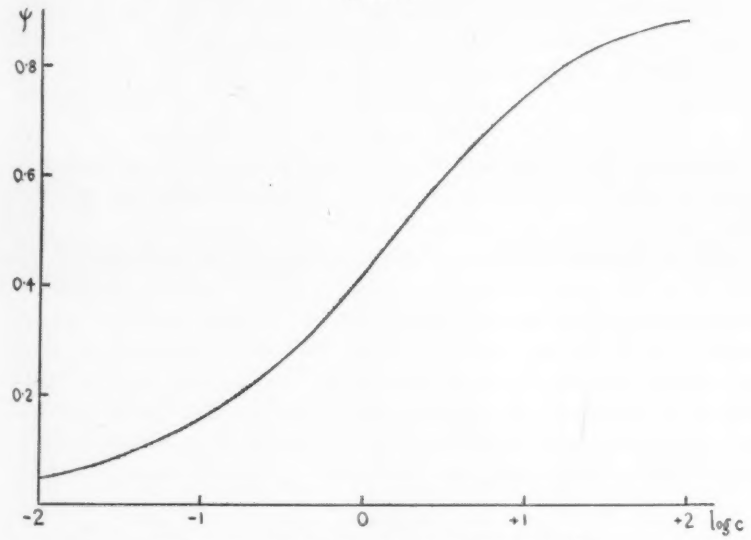
A numerical example follows with $t_0 = 80°$ C. and $a = 0.025$ ($x_0 = 2$). Without any additional terms ψ should be taken 35° and correspondingly $c = 1.128$. This means that with $2h = 2$ cm., and $k = 1 \times 10^4$ abs. P becomes $\sim 9 \times 10^{-5}$ (a heat resistance of a few cm. brick packing on each side). Calculating without correction terms v becomes 0.1442 and $x_b = 2.758$.

Taking now $\gamma = 1$ and computing the correction terms in (30) Θ becomes 35.032° and v from (32) 0.1368 with $A = 0.270$, $B = -0.00222$ and $C = -0.395$.

It is possible to repeat the whole process once more, by computing A, B and C by means of the improved values for Θ and x_b, the latter from (28). This done, the new value for v will be 0.1365, that is practically the same as before.

It may be added that the assumed value $\gamma = 1$ means an average additional term in the conductivity of about 10 per cent., according to (16), thus causing a decrease in the breakdown strength of ~ 5.5 per cent.

FIG. 1.



Auxiliary function $\psi - \log c$ for numerical computations.

The actual value of the breakdown voltage can be computed from v by (19). With $\sigma_0 = 0.05$ abs. $= 5.5 \times 10^{-14}$ rec. ohms/cm., $\varphi_b = 545$ abs., thus the total voltage $(2\varphi_b) = 326$ kV, that is 158 kV/cm.

(*b*) In Sect. 3, the formulæ for small and large values for c have been given. For intermediate thicknesses the general equations have to be used. Figure 1 gives corresponding values of log c and ψ which are useful for any calculation. For numerical evaluation (46) can be replaced by the following:

$$\varphi_b = 2\sqrt[3]{\frac{kh \sin^4 \psi}{2a\sigma_0 b\psi \tan \psi}}\, e^{-x_b/3}. \qquad (50)$$

Let us now assume $k = 3 \times 10^4$ abs., $2h = 1$ cm., $a = 0.02$, $\sigma_0 b = 0.1$, $t_0 = 200°$ C. and $c = 5$, that is $P = 3.3 \times 10^{-6}$. Then from Fig. 1, $\psi = 0.665$. From (44):

$$x_b = 4.417,$$

and from (50):

$$\varphi_b = 47.5 \text{ abs.}$$

This value referring to the half separation, the breakdown voltage becomes 95 abs., or 28.5 kV_{eff}.

It has been shown in Sect. 1, that from 200° C. on A.C. may be treated according to the presented theory. Thus the data chosen correspond more to A.C. than to D.C. The conductivity for 0° C. is $\sigma_0 bE$, that is for low field strengths ($E \sim 3$ abs. $\sim$ 1000 V/cm.) 0.3. Taking the dielectric constant 4 and the frequency 60, that value would correspond to $\tan \delta = 0.0025$, which is the usual order for medium quality materials.

Since in electrical machinery temperature will rise with increasing demand in the near future, this type of presentation is of considerable importance. Its value is not influenced by the fact that the mechanism of the increase with temperature and fieldstrength of the conductivity is left open. Whether this mechanism is an ionic or electronic one,[8] the equations controlling thermal stability remain valid, thus justifying the above method of computation.

SUMMARY.

Thermal instability of dielectrics will be considerably influenced by a variation with field strength of the electrical conductivity. The case in which the distribution of the potential across the insulator is controlled by the conductivity alone is dealt with in the present paper. The treatment applies as well to D.C. generally as to A.C. for higher temperatures, thus has a fairly wide range of applicability. The conductivity is taken as a linear function of the field strength, in accordance with experiments, two special cases being dealt with quantitatively. It is shown by numerical computations how the deduced equations have to be used in actual instances.

[8] A. v. Hippel, *Journ. Appl. Phys.*, **8**, 815 (1937).

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

RESOLVING POWER AND DISTORTION OF AIRPLANE CAMERA LENSES.

The precision lens testing camera developed in the Bureau's Optical Instruments Section has proved particularly useful in testing of airplane camera lenses, where the measurements most commonly desired are focal lengths, distortion, and resolution. In the course of these measurements, it has been found that the manner in which resolving power of a given lens varies across the image plane is characteristic of the type of lens. The results also show that the practice of setting a lens in a camera so that the region of best imagery is at the center of the field does not always yield best average resolving power across the entire field. The distortions of lenses used in airplane cameras, on comparison with distortion measurements published a decade ago, are shown to have been reduced in that time.

A paper (RP1216) by F. E. Washer in the June number of the Journal of Research contains tabulations of the resolving power and distortion of lenses of three different types. A complete description of the process of selecting the image plane that gives best average definition is also given.

INDUSTRIAL USES FOR SILVER.

As noted in Technical News Bulletin 265, the American Silver Producers' Research Project has been extended for another year, terminating May 31, 1940.

It has been decided to concentrate attention during this final year of the Project on work relating to commercialization of silver-lined containers, silver alloys, electrical brushes, fungicides containing silver, and corrosion studies. The research work connected with the container and alloy programs is concentrated at the Bureau where the staff now

* Communicated by the Director.

consists of nine research associates [2] with a part-time helper and a research clerk. The work of this staff is about equally divided between electroplating studies and alloy research. A silver-plating plant has been set up and will be used to prepare material for fabrication by commercial organizations which are cooperating with the Project in its effort to develop silver-lined containers.

The research on fungicidal properties of silver is being carried on at Cornell University by L. W. Nielsen under the direction of Prof. L. M. Massey; that on brushes is under the supervision of Prof. S. B. Wiltse at Rensselaer Polytechnic Institute; and the research on corrosion resistance of silver is in progress at Lehigh University where J. M. Thomas is working under the direction of Prof. Allison Butts.

SOUND INSULATION OF WALLS AND FLOORS.

Building Materials and Structures Report BMS17, recently released, contains a general discussion of the Bureau's work on sound insulation. The factors which control the transmission through homogeneous and nonhomogeneous walls are discussed.

A homogeneous wall which would give a higher degree of sound insulation would have to be excessively heavy. Therefore, where sound insulation is desired, it is necessary to build nonhomogeneous structures. The ideal structure for a sound insulated room is a box within a box without any connecting ties between. Although this is impossible, an approximation to it can be made by the use of special supports at as few points as possible.

The effect of openings is discussed and it is shown that a very small opening such as the crack under a door will almost completely destroy the sound insulating value of any wall.

Masking effects are discussed and attention is called to the fact that only a small amount of general noise makes a wall appear to be a much better sound insulator than it really is.

Attention is called to the fact that where quiet conditions are required within the building, care should be taken to pick

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[2] A. J. Dornblatt, A. M. Setapen, A. C. Simon, C. J. LeBrasse, C. W. Pimper, J. T. Lumley, and G. G. Luther.

a locality for the building where the noise level is not excessively high. Also, when it is desirable that some rooms should be quieter than others, they should be placed where there will be the least disturbance from normal noises which occur in the building.

The report summarizes the data on the construction of many of the panels which have been tested at the Bureau, and their corresponding sound insulating properties.

Copies of BMS17 are obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 10 cents each.

CATHODIC PROTECTION OF PIPE LINES.

The use of cathodic protection has rapidly increased since the first installation on gas transmission lines in 1930, until now practically all of the large companies are using this method to prevent the corrosion of parts of their pipe line systems. Cathodic protection is usually installed on lines that were properly coated before they were laid. By applying current cathodically the potential of the entire pipe line is lowered with respect to a reference half-cell in the surrounding soil so that current flows toward the pipe through any imperfections in the coating. However, by careful design and proper location of anodes from which the drainage current is discharged into the soil, it has been found to be economical in certain cases to apply cathodic protection to bare lines such as gas pipe lines of large diameter. On bare oil lines, which are of smaller diameter, reconditioning operations still seem to be preferable to cathodic protection if the occurrence of leaks should become excessive.

At the meeting of the Petroleum Industry Electrical Association in Houston, Texas, the afternoon of May 4 was devoted to a paper entitled "Applications of Electrochemistry to Cathodic Protection" which was presented by Scott Ewing, Research Associate of the American Gas Association at the Bureau. In this paper some electrochemical principles were discussed which will be useful to the cathodic protection engineer by helping him make more accurate voltage measurements and by giving him a better understanding of the

corrosion process. The design of copper-copper sulfate and cadmium-cadmium sulfate half-cells has been improved to correct some of the faults of the half-cells previously used. (See Technical News Bulletins 264 and 265, March and April, 1939.) A brief description of these improved half-cells was given, together with temperature correction curves. With these half-cells the potential difference between two points in the soil can be measured with an error not greater than 2 mv.

A consideration of the potentials and currents in a corroding pipe line indicates that in some cases it should be possible to apply cathodic protection to bare pipe lines of small diameter. The protective current should be drained from the pipe line in places where the reference half-cell has a large positive potential with respect to the pipe line. In such places the pipe is usually found to be discharging current into the soil. By locating anodes so as to take advantage of the galvanic currents in the pipe line, a much greater length of line can be protected with one anode. The potential of the pipe with respect to a reference half-cell is not appreciably changed except in the originally anodic area near the anode. This is probably the only part of the line that really needs protection. The feasibility of the method depends upon the distribution and stability of the originally anodic areas along the pipe line. Whether it is economical or not will depend upon the relative costs of cathodic protection and probable future reconditioning.

ALLOYS FOR ELECTRICAL HEATING ELEMENTS.

The manufacturers of electric heating devices, from toasters to furnaces, as well as the users of these devices, have always been vitally interested in the life and maximum operating temperature of the heating unit. Various types of tests, such as the "Accelerated Life Test for Metallic materials for Electrical Heating" B76–38 of the American Society for Testing Materials, have been devised with the view of predicting the life expectancy of a heating element under specified conditions of operation. The operating temperature of the material probably has more effect upon

the results obtained from these tests than any other single variable which must be controlled. Most tests of this nature are conducted by heating the materials electrically, and in such cases the temperature of the materials (usually in the form of small wires) is most conveniently measured with an optical pyrometer. The temperature observed when an optical pyrometer is sighted upon the surface of a material heated in this way, is known as the apparent temperature. In order to obtain the true temperature which determines the life of the material, some knowledge of the radiating characteristics of the surface is required.

A paper presented before the American Society for Testing Materials by William F. Roeser of the Bureau's Pyrometry Section, gives the relation between apparent temperature and true temperature of the various types of heating element materials used in this country. When samples of the different types of materials were heated to the same apparent temperature of 2200° F. in air, the true temperatures of the different materials ranged from 2221° to 2253° F. Although the difference between 2221° 2253° F. is not large, the information available indicates that the life of an element in air may be changed by 25 to 50 per cent. by changing the temperature of the material 25° F.

When these same materials were operated at the same apparent temperature of 2200° F. in purified hydrogen, the true temperature of the different materials ranged from 2260° to 2402° F. Results on some of the alloys in commercial hydrogen and nitrogen are also included.

This paper gives data needed to devise tests for determining the relative performance of different types of materials, not only in air, but also in atmospheres which are generally considered reducing.

Railroads at Work at the New York World's Fair 1939.—This great show will demonstrate, for the first time anywhere, the complete inner workings of a modern railway system. It will give the public opportunity to see an entire railway system in actual operation. It will show the complicated mechanism devised for the safety, speed and comfort of modern passenger travel. It will show facilities for the loading, hauling and distribution of freight and for the rapid and safe transit of perishables. It will be a dramatic presentation, designed to entertain, as well as inform the public on the country's greatest industry, its largest and most important public service. This thrilling spectacle will be presented on a huge scenic diorama 160 feet.in breadth and 40 feet in depth, covering about 7,000 square feet with back trackage—the largest ever built—in design embodying the topographical features of Eastern states. Over 3,500 feet of "o" gauge track has been laid for the operation and over this network 500 pieces of railway equipment, including 50 locomotives, will run. In perspective, spectators will be viewing operation over a landscape 50 square miles in area with approximately 40 miles of track that would be needed for a similar demonstration with life size equipment.

R. H. O.

THE FRANKLIN INSTITUTE.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesday, June 14, 1939.)

HALL OF THE COMMITTEE,
PHILADELPHIA, JUNE 14, 1939.

MR. WILLIAM G. ELLIS *in the Chair.*

The following report was presented for final action:

No. 3049: Deformation Recording Apparatus.

This report recommended the award of an Edward Longstreth Medal to Richard L. Templin, of New Kensington, Pennsylvania, "In consideration of the ingenious application of mechanisms resulting in the development of the Templin Automatic Autographic Deformation Recorder."

JOHN FRAZER,
Secretary to the Committee.

LIBRARY NOTES.

The Committee on Library desires to add to the collections of the Institute any technical writings of members who have had occasion to publish such material.

Literary contributions from author-members will be gratefully acknowledged, properly inscribed and noted in the Journal of the Institute.

Photostat Service. Photostat prints of any material in the collections can be supplied on request. Orders received in the morning are filled the same day. The cost for a print 9 × 14 inches is forty cents.

The library and reading room are open daily from nine o'clock A.M. until five o'clock P.M. Saturdays until 12 o'clock noon. 712 readers made use of the facilities during the twenty-six days of May.

RECENT ADDITIONS.

AERONAUTICS.

LOUDY, FLAVIUS E. Metal Airplane Structures. 1938.

ARCHITECTURE AND BUILDING.

HALE, ROBERT S. Welded Steel Construction. 1938.
HEID, H., AND A. KOLLMAR. Die Strahlungsheizung. 1939.

ASTRONOMY.

An Introduction to the Study of Stellar Structure. 1939.

BIBLIOGRAPHY.

Engineering Index 1938. 1939.

BIOGRAPHY.

CHAMBERLAIN, RUDOLPH W. Beacon Lights of Literature. Book 2. 1933. (Contains Autobiography of Benjamin Franklin.)

CHEMISTRY AND CHEMICAL TECHNOLOGY.

American Gas Association. Proceedings. Twentieth Annual Convention 1938.

BRAUER, OSCAR L. Chemistry and its Wonders. 1938.

Chemical Society. Annual Reports on the Progress of Chemistry for 1938. Vol. 35. 1939.

DANIELS, FARRINGTON. Chemical Kinetics. 1938.

EVANS, R. C. An Introduction to Crystal Chemistry. 1939.

FARKAS, A., AND H. W. MELVILLE. Experimental Methods in Gas Reactions. 1939.

HISCOX, GARDNER D., AND T. O'CONNOR SLOANE. Fortunes in Formulas. 1939.

Inorganic Syntheses. Volume 1. 1939.

KAUSCH, OSKAR. Das chemische Feuerlöschwesen. 1939. Chemie und Technik der Gegenwart. Bd. 21.

NORD, F. F., AND R. WEIDENHAGEN, Editors. Ergebnisse der Enzymforschung. 8 Band. 1939.

PRODINGER, WILHELM. Organische Fällungsmittel in der quantitativen Analyse. Zweite umgearbeitete und erweiterte Auflage. 1939. Die chemische Analyse, 37 Band.

SCHULTZ, GUSTAV. Farbstofftabellen. Siebente Auflage neubearbeitet und erweitert von Dr. Ludwig Lehmann. Ergänzungsband 2. 1939.

TRESSLER, DONALD K., MAYNARD A. JOSLYN, AND GEORGE L. MARSH. Fruit and Vegetable Juices. 1939.

CLOCK AND WATCHMAKING.

DE CARLE, DONALD. With the Watchmaker at the Bench. Third Edition. 1938.

GORDON, G. F. C. Clockmaking Past and Present. 1925.

HOOD, GRANT. Modern Methods in Horology. Fourth Edition. 1926.

LANGMAN, H. R., AND A. BALL. Electric Horology. Third Edition, Revised and Enlarged. 1935.

EDUCATION.

ADAM, T. R. The Civic Value of Museums. 1937.

ADAM, T. R. The Museum and Popular Culture. 1939.

GEOLOGY.

JOHNSON, GAYLORD. The Story of Earthquakes and Volcanoes. 1938.

MATHEMATICS.

LEVINSON, HORACE C. Your Chance to Win: the Laws of Chance and Probability. 1939.

MECHANICAL ENGINEERING.

LIST, HANS, Editor. Die Verbrennungskraftmaschine. Heft 1–2, 7. 1939.

MINING ENGINEERING.

Internationale Tagung der Leiter grubensicherheitlicher Versuchanstalten. 3rd Dortmund. 1935. Bericht. 1939.

PHOTOGRAPHY AND PRINTING.

ANGERER, E. v. Wissenschaftliche Photographie. Zweite gänzlich neubearbeitete Auflage. 1939.

CLARK, WALTER. Photography by Infrared. 1939.

Handbuch der modernen Reproduktionstechnik. Bd. 1–5. 1934–1938.

KARCH, R. RANDOLPH. Printing and the Allied Trades. n.d.

SPENCER, D. A. Colour Photography in Practice. 1938.

PHYSICS.

EGLOFF, GUSTAV. Physical Constants of Hydrocarbons. Volume 1. 1939. American Chemical Society Monograph Series. No. 78.

KLEMPERER, OTTO. Electron Optics. By the Research Staff of Electric and Musical Industries, Ltd. 1939. Cambridge Physical Tracts.

Summer Conference on Spectroscopy and its Applications. 6th. Cambridge, Mass. 1938. Proceedings. 1939.

NOTES FROM THE BARTOL RESEARCH FOUNDATION.

ON THE VARIATIONS OF COSMIC RADIATION DURING MAGNETIC STORMS.*

BY

THOMAS H. JOHNSON.

During the large magnetic storm of April 1937, Forbush [1] and Hess and Demmelmair [2] have reported significant decreases of cosmic-ray intensity at Cheltenham, at Huancayo, and on the Hafelekar. Preliminary reports of similar variations have been communicated to the Department of Terrestrial Magnetism of the Carnegie Institution from Mexico and New Zealand. The changes in cosmic-ray intensity were apparently world-wide in character and at the three stations first named the lowest daily mean of cosmic-ray intensity was about four per cent. less than the mean of the 36 hours preceding the impetus of the first magnetic disturbance. For the corresponding times there was a change in horizontal magnetic field of 0.4 per cent. so that for this particular storm

$$dJ/J \approx 10 dH/H. \qquad (1)$$

In accordance with the Störmer-Lemaitre-Vallarta theory of geomagnetic cosmic-ray effects, the variation of the cosmic-ray intensity during a magnetic disturbance can be calculated if it is assumed that the disturbance can be represented by a variation in the Earth's magnetic moment. In the complete paper the relation between the change of magnetic moment and the change in cosmic-ray intensity is calculated.

A comparison of the theoretical calculations with the observed variations of cosmic-ray intensity during the storm

* An abstract of a paper published in full in *Terrestrial Magnetism and Atmospheric Electricity*, **43**, 1 (1938).

[1] S. E. Forbush, *Phys. Rev.*, **51**, 1108 (1937).

[2] V. F. Hess and A. Demmelmair, *Nature*, **140**, 316 (1937).

of April 1937 reveals that the moment found necessary to produce the observed variations is of the order 150 times greater than any value simply reconcilable with that demanded by the theory aforesaid.

THE PRODUCTION OF MUTATIONS IN DROSOPHILA WITH NEUTRON RADIATION.*

BY

MARY A. NAGAI† AND GORDON L. LOCHER.

It is to be expected that the chief biological effects of fast neutrons will arise from the ionization along paths of recoil protons (hydrogen nuclei) that they eject by elastic collisions. Neutrons for this experiment were obtained with the "radium bomb" of the AMERICAN ONCOLOGIC HOSPITAL (NEWCOMET and HUGHES 1935), by allowing part of the gamma radiation from 4 grams of radium to pass through 485 grams of beryllium metal in a cylinder 8.0 cm. in diameter and 9.0 cm. in height. The radium holder, containing eighty 50-mg. needles, was put in contact with one end of the beryllium cylinder, inside the massive lead bomb.

Gamma-rays whose energies exceed 1.6 Mev. (millions of electron volts) can disintegrate beryllium nuclei, with the emission of neutrons, by the "photo-nuclear effect"; the neutrons thus obtained are sometimes called "photo-neutrons." The maximum ranges, in air, of protons ejected by unscattered neutrons from the present source are, according to the Cornell University energy-range curves of 1937, 0.22 cm. and 1.1 cm., respectively. In water, the corresponding ranges are, approximately, 2.2 microns and 11 microns, respectively. Most of the recoil protons will, of course, have much smaller ranges, since their paths are oblique to the directions of incidence of the impinging neutrons.

The fast neutrons used here are liberated with two distinct kinetic energies which are probably not greatly altered before the particles reach the flies. The slow neutrons, however,

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* Reprinted, in part, from a paper published in full in *Genetics*, 23, 179 (1938).

† Miss Nagai is at the Rice Institute, Houston, Texas.

undoubtedly have a continuous range of energies that extend from those of the unscattered neutrons to zero, mainly as the result of scattering in the paraffin. The total number of fast neutrons in the "slow" group might be roughly 25 per cent. as great as in the fast neutron group.

The distance of the perpendicular from the "line of centers" of the radium bomb to the mid-position of the flies in the vials was 12.6 cm. The distance from the center of the beryllium source to the mid-position of the flies was 11 cm. A cadmium filter 0.023 cm. in thickness was used to filter out the very slow neutrons that may reach the flies as a result of scattering in beryllium and paraffin. The scattering in the beryllium, however, has been shown to be negligible. The flies thus protected by the cadmium filter received the "fast" neutron treatment.

The "slow" neutron flies were placed at the same distance from the beryllium source in a paraffin box which weighed 4.5 pounds. The paraffin serves to slow down the neutrons by multiple scattering with hydrogen; its use for this purpose is general practice in neutron experiments. The paraffin facing the beryllium source was 1.2 cm. in thickness, while that on all other sides of the box presented a thickness of at least 2.4 cm. to neutrons incident from the beryllium source or scattered into the box by the lead of the bomb. The side of the box farthest from the bomb was about 5.0 cm. thick and served as a backward-scatterer for the neutrons. This arrangement was chosen for its relatively high yield of slow neutrons, on the basis of a previous series of experiments with the production of artificial radioactivity in a special Geiger-Müller counter with a silver cathode. The distance of the "slow" neutron-treated flies from the beryllium source was approximately the same as that given for the "fast" neutron flies.

To determine the effect of neutrons on the mutation rate, adult eosin males of *Drosophila melanogaster* were treated and lethals in the sex chromosome looked for. The lethals were detected by MULLER'S ClB method. One treated male was used per bottle in the P_1, and the F_1 Bar females were reared in vials. The lethals were located with regard to *w*^{e}*vf*. The three groups of flies were, namely, (1) the neutron-treated, (2) the corresponding gamma-ray controls, and (3) the non-

irradiated controls which did not receive any kind of radiation. They all received identical handling except during treatment period. The neutron-treated flies and the corresponding gamma-ray control flies were not exposed to their respective radiations at the same time. They were usually exposed alternately, for equal intervals.

The results of a series of experiments with dosages of 16 to 40 hrs. are shown in Table I.

TABLE I.

Series.	No. of F_1 Bred.	Number of Lethals.			Mutation Rate.
		Total.	1 per Male.	2 or More per Male.	
1. Fast neutrons...	4312	44	18	26	0.01021±0.00103
2. Slow neutrons...	1504	5	5	0	0.00332±0.00100
3. Gamma-rays....	4764	19	19	0	0.00399±0.00062
4. No radiation....	4772	12	12	0	0.00252±0.00049

The combined results got with the fast neutrons are definitely significant in comparison with the gamma-ray controls. The difference between the frequency rates in 1 and 3 is six times the probable error in 1 and ten times the probable error in 3. The slow neutrons, on the other hand, give no significant result in comparison with the gamma-ray controls, the difference in the two rates being only 0.62 times the probable error in 2 and 1.8 times the probable error in 3. The gamma-rays are having a slight effect. The difference between the frequency rates in 3 and 4 is 2.3 times the probable error in 3 and 3.0 times the probable error in 4.

The number of lethals per male is noteworthy. The total number of males that yielded lethals in the fast neutron-treated series was 25, of which 11 yielded two or more lethals apiece (giving the total of 26 shown in the above summary). This contrasts sharply with the results of the gamma-ray controls and the remaining series, in that there was no tendency for any such grouping of the lethals in them.

Only one inversion was obtained in the present series of experiments. The inversion, located in region I (between w^e and v), was found among the flies treated for 36 hours with fast neutrons.

THE INTENSITY OF THE PRIMARY COSMIC RADIATION AND ITS ENERGY DISTRIBUTION.*

BY

THOMAS H. JOHNSON.

The cosmic-ray intensity when plotted against depth in the atmosphere rises from some low value at the top of the atmosphere, passes through a maximum, and then falls off at greater depths. The initial rise demonstrates the importance of secondary effects in the measured intensity and one is led to inquire what the primary intensity would be if the apparatus could be elevated above the atmosphere. Because of wall effects, which would become appreciable under those conditions, in the ionization measurements, and because of magnetic bending of secondaries [1] in the rarified atmosphere at great heights, the actual measurements at the greatest attainable heights must always exceed the primary intensity, but it is possible to arrive at the number of primary rays by means of a simple calculation.

The total energy expended in the production of ions within a column of air of unit cross section and infinite depth is equal to the energy incident upon its upper surface. This energy divided by the average energy of a primary cosmic ray is equal to the number of primary cosmic rays per unit area. The recent balloon flights of Bowen, Millikan, Neher and Haynes [2] have supplied the data required for the computation of the energy expended in the atmosphere at the latitudes 3° N., 39° N. and 52° N. geomagnetic latitude and the earlier results of Millikan and Cameron [3] can be used for the greater depths where latitude effects are negligibly small. The results of integrations under these curves, reduced to the total number of ions in an infinitely deep column of air one square centimeter in cross section, are given in the first row of Table I. The major part of the ionization takes place in the atmosphere; out of the total of 1×10^8 ions at 52° N. only 2.3×10^6 ions

* Reprinted from the *Physical Review*, **53**, 499 (1938).

[1] Kulenkampf, *Naturwiss.*, **21**, 25 (1933).

[2] Bowen, Millikan and Neher, *Phys. Rev.*, **52**, 80 (1937); Millikan, Neher and Haynes, *Phys. Rev.*, **50**, 992 (1936).

[3] Millikan and Cameron, *Phys. Rev.*, **37**, 235 (1931).

TABLE I.

Intensity Data for Cosmic Rays at Various Latitudes.

Geomagnetic Latitude.	3° N.	39° N.	52° N.
Ions per cm.² per sec.	$3 \cdot 10^7$	$5.4 \cdot 10^7$	$10 \cdot 10^7$
Energy per cm.² per sec. (electron volts)	$1 \cdot 10^9$	$1.7 \cdot 10^9$	$3.2 \cdot 10^9$
V, low energy limit by the earth's field	$15 \cdot 10^9$	$8 \cdot 10^9$	$2 \cdot 10^9$
Upper limit to the number of cosmic rays per cm.² per sec.	0.064	0.215	1.6
Average energy per ray $n = 3$ law with limit at 4.4×10^9	3×10^{10}	1.6×10^{10}	0.88×10^{10}
Probable number of rays per cm.² per sec.	0.032	0.11	0.36
Probable number per minute	1.9	6.5	21.8

are produced below sea level and only 1×10^6 below 40 meters of water. The total energy, listed in the second row, is equal to the ionization multiplied by the energy required to produce one ion pair, assumed equal to 33 ev.

The minimum energies of the primary cosmic rays for each latitude are given by the theory of the cosmic-ray orbits in the earth's magnetic field, developed by Lemaitre and Vallarta.[4] Strictly speaking the minimum energy also depends upon the direction, but to a first approximation the value for the vertical direction may be taken as a mean value for the latitude in question. These minimum energy values are listed in the third row of the table. An upper limit to the number of rays may now be found by dividing the total energy by the minimum energy. The numbers found in this way are listed in the fourth row of the table. The average energy per ray can be computed from the minimum energy if the energy distribution function is known. This distribution would be uniquely determined by the data if the measurements had extended over a continuous range of latitudes,[5] but in order to interpolate between the experimental points and to extrapolate beyond them into the higher energies above the low energy limit for the equator, it is convenient to assume some form of the energy distribution with two disposable constants and to determine these from the data for the two lowest latitudes. The intensity at the highest latitude may be affected by the

[4] Lemaitre and Vallarta, *Phys. Rev.*, **50**, 493 (1936).

[5] This was pointed out independently and nearly simultaneously by H. Zanstra, *Naturwiss.*, **22**, 171 (1934), and the writer, *Phys. Rev.*, **45**, 574 (1934).

existence of a low energy limit to the primary cosmic radiation imposed by a solar magnetic field which introduces additional considerations. A reasonable distribution function will have a large value for low energies, will vanish asymptotically for high energies and will be positive and continuous over the range above the low energy limit. Below the low energy limit the function will be zero. An analytically convenient form of function is

$$\begin{aligned} j(V) &= A\,V^{-n} \qquad V > V_0, \\ j(V) &= 0 \qquad\quad V < V_0, \end{aligned} \tag{1}$$

where $j(V)dV$ is the number of rays per horizontal square centimeter per second in the primary radiation in the energy range from V to $V + dV$. The total energy in latitude λ per cm.^{2} per sec. is

$$E_\lambda = \int_{V_\lambda}^{\infty} Vj(V)dV = A\,V_\lambda^{-(n-2)}/(n-2); \tag{2}$$

the total number of rays per cm.^{2} per sec. is

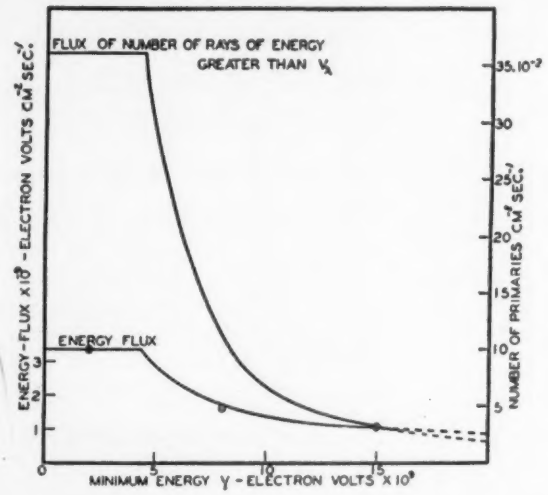
$$J_\lambda = A\,V_\lambda^{-(n-1)}/(n-1), \tag{3}$$

and the average energy per ray is

$$\bar{V}_\lambda = (n-1)\,V_\lambda/(n-2). \tag{4}$$

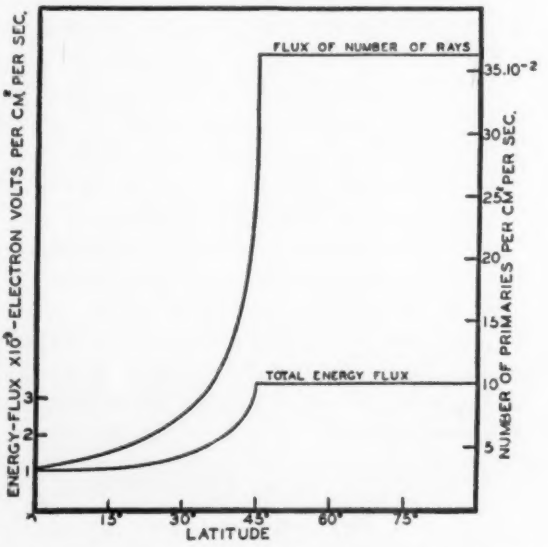
If n is determined from the experimental points for 3° N. and 39° N., it is found that an exact fit is realized with $n = 2.87$; the data are approximated within reasonable accuracy by $n = 3$, $A = 15 \cdot 10^{18}$. A plot of the total energy per cm.^{2} per sec. by rays of energy greater than V, according to this distribution, is given in curve *I* of Fig. 1. The points realized from the integration of the experimental data are shown as circles. In order to include the point at 52° N. it is necessary to assume that the lower energy limit occurs at 4.4×10^9 ev. (If an exponent less than $n = 3$ were chosen this point would shift to slightly lower energies.) This corresponds to a knee in the latitude *vs* intensity curve at 45° which is in close agreement with the position of the observed knee. In the same figure the number of primary cosmic rays per cm.^{2} per sec. of energy greater than V is also plotted according to the corresponding distribution, Eq. (3) with $n = 3$. Figure 2 shows

FIG. 1.



The flux of the number of cosmic rays and the cosmic-ray energy for rays of energy greater than V_λ.

FIG. 2.



The latitude effect of the primary cosmic radiation plotted in terms of numbers of rays per cm.² per sec. and in terms of the total energy flux.

the same quantities plotted against latitude. In calculating the number of rays an average energy equal to twice the minimum energy, according to Eq. (4) with $n = 3$, has been used.

The total number of cosmic rays incident upon the entire surface of the earth is given by the integral

$$N = 4\pi R^2 \int_0^{\pi/2} J(\lambda) \cos \lambda d\lambda = 8.0 \times 10^{17} \text{ rays per second.}$$

It is known that most of the primary cosmic rays are positive.[6] If they were all positive, the cosmic-ray current to the earth would be 0.13 amperes. In the absence of other currents this would charge the earth up at the rate of 180 volts per second. The total power of the cosmic-ray primaries is about one million kilowatts.

In the last row of Table I the number of primary cosmic rays per cm.^{2} per minute is given for each of the three latitudes. Since approximately one [7] cosmic ray per minute is incident upon a horizontal square centimeter at sea level these numbers represent approximately the ratios of the intensities at the top of the atmosphere to those at sea level.

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[6] T. H. Johnson, *Phys. Rev.*, **45**, 574 (1934).

[7] According to Street and Woodward this number is 1.25 rays per minute at sea level. *Phys. Rev.*, **46**, 1029 (1934).

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

Improvement and Development of the Cyclotron.—ALEXANDER J. ALLEN. (Physics Department of the Biochemical Research Foundation of the Franklin Institute, Philadelphia, Pa.) Improvements on the cyclotron have been a major project of the Physics Department of the Biochemical Research Foundation since December, 1938. Increasing the reliability and efficiency of the machine and incorporating new developments have been the chief aims of the Department. Additional measuring and controlling apparatus have also been made.

One of the most significant improvements in the cyclotron has been the design and construction of a new type of ion source, which consists of a tungsten ribbon in place of the tungsten spirals formerly in use. The direct current supply for this source has been replaced by a high frequency alternating current, the frequency being high enough so that the ribbon will be force free in the magnetic field and will not distort or break. In addition to this type of ion source a capillary arc has been constructed, which has the advantage of releasing the ions at a point where they can be most efficiently accelerated in the cyclotron. Such arcs have been reported to produce a five-fold increase in efficiency, but unfortunately they have been very short-lived. It is hoped that improvements incorporated in the present arc will give it longer life. The same high frequency power is used for this capillary arc, although it was necessary to build an apparatus to supply 4 amperes at 200 volts D.C. The apparatus was built entirely in the laboratory, including transformers, mercury rectifier tubes, etc. Two complete new sets of mercury rectifiers for the plate supply of the oscillator have been made which are considerably improved in design over the ones formerly used.

The previous Dee supports often became overheated causing leaks in the vacuum chamber. The mechanism to

adjust the Dees was also unsatisfactory. To eliminate these difficulties entire new Dee supports have been designed and constructed. A new deflector condenser has been made to replace one which was overloaded.

A new pumping system has been designed and installed which, it is anticipated, will be more efficient than the previous system. This includes a reliable vacuum valve and a cooling trap in which large amounts of carbon dioxide can be placed. A new trap for liquid nitrogen, made of spun copper with a monel metal insulating neck, has been installed to replace the glass trap formerly in use. In addition, three liquid nitrogen containers have been made from spun copper and stainless steel with monel metal insulating necks. Soft solder, used in the former containers, has been replaced with silver solder; this enables obtaining a higher vacuum, which gives increased insulating power.

Occasionally when the cyclotron is in operation a spark breakdown occurs and releases gas in the vacuum chamber. An automatic deuterium regulator has been installed which shuts off the supply of deuterium when such a gas burst occurs and turns it on when the pressure is again diminished. Considerable strain on the apparatus is associated with these spark or voltage breakdowns. Such surges can be eliminated by the use of a constant current apparatus which limits the current to a pre-determined amount. The current regulating system formerly used was simply a variable column of flowing water which was inefficient and not dependable. A new constant current apparatus has been devised which will give greater flexibility of operation. It is to be used also as a current controlling mechanism, that is, the amount of current delivered to the cyclotron can be varied from a small to a large amount. This apparatus is nearly ready for trial.

The operation of a cyclotron depends upon the homogeneity of the magnetic field. Inhomogeneities in the field have delayed the operation of certain of the cyclotrons now under construction. Apparently no such inhomogeneities occur in the magnetic field of the Biochemical Research cyclotron, but a thorough plot of the field is being made. Such a plot will give essential information on shimming, without which cyclotrons have not been efficiently operated.

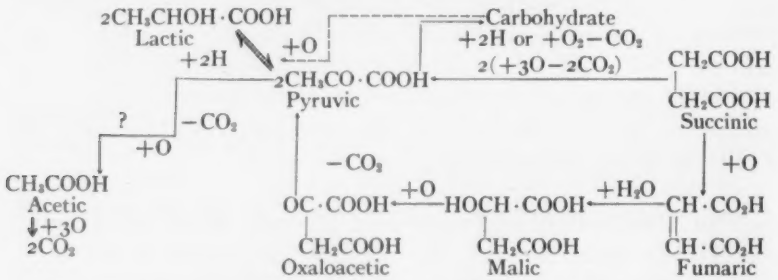
In addition to these mechanical improvements on the cyclotron iteself, several types of measuring apparatus have been developed. For example, the output of the cyclotron is measured in microampere hours, and in making supplies of radioactive material it is desirable to know the number of microampere hours with which the material has been irradiated. A current integration apparatus has been constructed to determine this quantity for all irradiated samples. A more satisfactory Geiger counter to measure the artificial radioactivity of the weak radiations from sulfur has also been devised. In addition, a scaling circuit has been made which will extend the counting rate of a Geiger counter up to 16-fold. In some instances an F.P. 54 amplifier is more desirable than a Geiger counter or an electroscope for measuring artificial radioactivity. An apparatus for using one of these amplifiers to record automatically the activity of a given radioactive sample has been made. Work has also been done toward the standardization of neutron measurements.

The Metabolism of Lactic and Pyruvic Acids in Normal and Tumor Tissues. VI. Ox Retina and Chick Embryo.—M. E. GREIG, M. P. MUNRO and K. A. C. ELLIOTT. (*Biochemical Journal* **33**: 443, 1939. See also Elliott *et al. Biochem. J.* **28**: 1920, 1934; **29**: 1937, 1935; **31**: 1003, 1021, 1268, 1937.) A paper under the above title reports the results of the last of a series of studies on the metabolism of lactic and pyruvic acids, and of substances derived from these acids, in various animal tissues. In the following outline a survey of the main points of the earlier work is given, as well as a summary of the paper of Greig *et al.* Lactic and pyruvic acids are well known to occupy central positions in the metabolism of carbohydrate and other food-stuffs, and excessive production of lactic acid is one of the outstanding characteristics of cancer tissue. The study was undertaken in order to throw light on the fate of these substances in normal and tumor tissues.

The method of study consisted in immersing thin slices of the tissues in a medium of pH 7.4 containing bicarbonate and the various salts of serum in physiological concentration under an atmosphere of 95 per cent. O_2 or N_2/5 per cent. CO_2. By a manometric method the O_2 uptake, respiratory CO_2

evolution, and acid formation or removal, were measured. The apparatus used for the manometric work was designed by Dixon and Keilin and the details of its use were described in the first paper of this series. This apparatus permits simultaneous and separate estimation of O_2 uptake, respiratory CO_2 evolution, and CO_2 liberation or absorption by the bicarbonate-containing medium as a result of acid formation or removal. The production or removal of lactate, pyruvate, malate, oxaloacetate, succinate, glycogen, and total carbohydrate were determined by analytical methods.

The work indicated that, in kidney cortex slices, the changes shown in the following diagram occurred



In the presence of additions of all the acids shown in the diagram, kidney cortex caused a rapid removal of acid groups which was accompanied by increased O_2 uptake and a change in the R. Q. (CO_2 evolution/O_2 uptake). The cycle of transformations, −2 pyruvic → succinic → fumaric → malic → oxaloacetic → 1 pyruvic,—involves O_2 usage, CO_2 evolution and acid removal. Each step of the cycle was proved. In the presence of pyruvate the formation of succinate was shown; when malonate, which inhibits succinate oxidation, was also present, succinate accumulated in considerable amounts. The oxidation of succinate to fumarate and the conversion of fumarate to malate are well known to occur in all normal tissues and were readily observed. The first product of malate oxidation by tissue enzymes is known to be oxaloacetate, and the production of a keto-acid from malate was found. Oxaloacetate decomposes spontaneously to pyruvate. However, animal tissues do not accelerate the simple anaerobic decarboxylation of oxaloacetate to pyruvate and it is probable

that the spontaneous process is too slow to account for the rapid removal of malate, oxaloacetate, etc. Some unknown process must be involved in the oxidative removal of oxaloacetate. Greig and Elliott, in unpublished experiments, found that oxaloacetate is removed by kidney cortex in the presence of oxygen more rapidly than anaerobically in the presence or absence of tissue. They also found that citrate and α-ketoglutarate are rapidly metabolized and may be intermediate steps in the cycle after oxaloacetate. The cycle does not account for the whole metabolism of pyruvate. It is probable that some acetate was formed and this could be oxidized by kidney slices, though not as rapidly as pyruvate itself. More of pyruvate and of the other substances was used up than could be accounted for by complete oxidation and it was found that a synthesis of carbohydrate occurred in about the amount necessary to make up the balance sheet of pyruvate disappearance. The fact that succinate, fumarate, and malate, besides pyruvate and lactate, also gave carbohydrate synthesis was added evidence for the cyclic relations of these substances. The particular carbohydrate formed was not identified but it appeared not to be glycogen.

Sliced kidney cortex is the only tissue in which pyruvate seems to be removed mainly by the cycle. Liver, brain, testis and two types of tumor tissue were unable to oxidize malate at an appreciable rate though these tissues oxidized lactate and pyruvate rapidly. In these tissues very little succinate was formed from pyruvate. In liver, carbohydrate synthesis occurred with lactate and pyruvate but not with the other substances, no carbohydrate was synthesized by the other tissues. The tumor tissues studied oxidized lactate only slowly and unlike all normal tissues were unable to oxidize succinate to fumarate at an appreciable rate.

There seemed little doubt that in most tissues lactate was first oxidized to pyruvate. The reactions shown in the diagram and others not yet clarified account for pyruvate removal in kidney cortex. The method of pyruvate removal in the other tissues is not yet clear. Testis was found to remove pyruvate at a rapid rate under anaerobic conditions by a dismutation whereby two molecules of pyruvate gave one molecule each of lactate, acetate, and CO_2. In other tissues

pyruvate was used up only slowly in the absence of oxygen, and in no tissue could this dismutation account for the whole rapid aerobic removal of pyruvate.

Though the continuous production of lactic acid from glucose even in the presence of oxygen is a characteristic of cancer tissue, it was found that normal tissues also produce lactic acid aerobically very rapidly for a short time but the activity disappears fairly early under the experimental conditions.

In the last paper of the series, ox retina and chick embryo were added to the number of tissues examined. It was known that retina resembles cancer tissue in producing lactic acid rapidly and continuously even in the presence of oxygen, and that both these tissues produce lactate rapidly anaerobically. Retina and embryo, like all the tissues other than kidney cortex, were unable to oxidize malate rapidly and, therefore, the kidney cycle does not occur in these tissues either. Like the other tissues they oxidized lactate and pyruvate quite rapidly but the intermediate products of oxidation were not identified. There was evidence that, in retina, lactic acid was first oxidized to some acid other than pyruvic acid, but it is difficult to imagine what this substance could be.

In the last paper the results of the series were discussed in relation to the theory of Szent-Györgyi according to which the oxidation-reduction pairs, succinate-fumarate and malate-oxaloacetate, are not merely intermediary metabolites but by reversible oxidation and reduction, act as catalysts of the oxidation of other substances. It was pointed out that the failure of most tissues to oxidize added malate is no evidence against Szent-Györgyi's theory since the sliced tissues may contain sufficient malate for catalytic purposes and any small amounts of oxaloacetate formed from added malate, if not removed immediately by other processes, would inhibit further malate oxidation. The succinate oxidation mechanism is present in all tissues, except tumor tissues, in sufficient amount to account for the normal respiration through succinate-fumarate catalysis, but the extra rapid oxidation which occurs in some tissues with added substrates can scarcely be all accounted for by succinate-fumarate catalysis, the succinate oxidizing mechanism not being active enough.

Electrophoretic Separation of the Antibody from Human Allergic Serum. I.—JOHN M. NEWELL, ALEXANDER STERLING, MORRIS F. OXMAN, SAMUEL S. BURDEN, and LAURA E. KREJCI. (Read before the American Association for the Study of Allergy at St. Louis on May 15, 1939, by Alexander Sterling. In press in the *Journal of Allergy*.) Sufferers from hay fever and asthma usually show decided reactions when water extracts of the substances to which they are sensitive are injected into the outer layers of their skins. These reactions are so consistent that they are used as guides in the determination of the causes of the trouble. It has been found also that such allergic persons have something in their blood serum which, when injected into the skin of a non-sensitive person, will sensitize it for a few millimeters around the site of injection. If the site is tested a few hours or days later with the extract to which the donor of the serum was sensitive, the same redness and swelling is observed as would occur in the skin of the donor. This so-called passive transfer is also used in diagnosis to exclude certain false reactions which may occur if the patient is tested directly.

In order to make a study of the sensitizing substance or antibody and to compare it with the antibodies which play such an important part in destroying bacteria and neutralizing toxins in the animal body, an attempt was made to separate it from other constituents of blood serum.

It has been known for several years that the passively sensitizing antibody in human serum is to be found in the pseudoglobulin fraction of the proteins. However, the chemical methods of separation used at that time were not exact, so that the division of globulin into euglobulin and pseudoglobulin varied with the method used and the amount of handling to which the original material was subjected.

A new method of isolating proteins from mixtures was used in the present studies. This was electrophoresis, which depends for its action on the fact that the electric charges on molecules in a solution vary and consequently the rates of electrophoretic migration of the molecules differ when an electric current is passed through the solution.

Arne Tiselius of Upsala, Sweden, has studied the problem of electrophoresis and evolved an apparatus which eliminates

some of the errors to which the method is susceptible. His apparatus is essentially a U tube with flat sides to enable a beam of light to be passed through it and also to facilitate overcoming the heating effect of the electric current. This U tube is divided into sections, two upper, two lower, and a bottom, all of which can be slid out of line, thus cutting them off for examination of their contents. The solution to be studied is put in the bottom and two lower sections. These are slid out of alignment to close them off from the upper sections. The latter and the rest of the apparatus, consisting of two large glass vessels for the electrodes and large tubes connecting these with the U tube, are filled with a saline buffer solution having a pH of approximately 8.1. The pressure on both sides is equalized by a siphon. The apparatus is placed in a bath kept at the temperature of melting ice. When sufficient time has elapsed for all parts to come to the same temperature, the sections of the U tube are pushed into line by plungers operated by air pressure. A sharp boundary is thus formed between the protein and buffer solutions. After the electric current of approximately twenty milliamperes has been started, new boundaries due to the differing rates of migration of the various components of the protein are found to move slowly away from the original position. A rod dipping into one of the electrode vessels is raised by clockwork so that it causes a gentle movement of liquid through the U tube and by adjusting this the boundaries can be moved at will. When sufficient separation has occurred one of the boundaries can be brought to the division between the upper and lower sections of the tube. The current is then shut off and the sections slid out of line and the apparatus taken apart. Thus one component of a mixture of proteins can be separated.

The position of the boundaries was followed by the Schlieren method in which a beam of light was passed through the U tube. Wherever there was a change in concentration in the solution the light ray was bent and stopped by a knife edge. Light rays which passed through the places where the concentration was uniform continued straight into a camera. By looking at the ground glass at the back of the camera dark lines could be seen where the boundaries were located.

By the use of this method Tiselius and others have found that serum usually contains four proteins which are separated in the order of their rates of movement as follows: albumin, alpha, beta, and gamma globulins. Gamma globulin or some extra component closely related to it contains the antibodies in the bloods of lower animals.

In the present study the aim was to determine which of the protein fractions contains the skin sensitizing antibody from the serums of allergic humans. Through the use of an apparatus made in Tiselius' laboratory fractionations of such serums were made. The fractions were tested on normal persons by passive transfer in the usual way. The experiments were successful in four cases and all of these showed the activity to be related to the presence of gamma globulin. No new protein fraction was found under these conditions, so it is probable that the antibody is not an extra constituent of serum.

As a check on these results the presence of another antibody in the serum fractions was determined by testing them for their ability to inhibit the destruction of the red cells of rabbits by the toxin from staphylococcus. This antibody is present to some extent in practically all human serums. In all of eight cases the antitoxic activity was found in those fractions which contained gamma globulin.

A separation of the serum from rabbits which had been sensitized by previous injections of ragweed pollen extract was made. The antibody, as shown by precipitation in the presence of ragweed extract, was also found associated with gamma globulin.

These studies are of predominantly theoretical interest. Though a single antibody has not been isolated, as has been the case with antibodies which form dissociable precipitates, the results show that one homogeneous fraction, the gamma globulin, containing the allergic as well as other antibodies, can be separated from human blood serum.

BOOK REVIEWS.

YOUR CHANCE TO WIN; THE LAWS OF CHANCE AND PROBABILITY, by Horace C. Levinson, Ph.D. 343 pp. New York, Farrar and Rinehart, Inc., 1939. Price $2.50.

Here is a book which gives the low down on a few of the more popular games of chance. Roulette (The Monte Carlo variety, not to be too closely compared with the zero plus double zero United States brand), coin tossing, craps, poker and bridge are all subjected to mathematical analysis in an entertaining and instructive way. A few of the conclusions are:

In a series of tosses with a coin the probability for a run of any number, n, of consecutive heads is $(1/2)^{n+2}$.

The probability of the "come" in craps is 0.49293. The "net expectation" of the first game in rubber bridge is 350 points although bridge rules allow only 300 points in case the rubber is interrupted.

In bridge the probabilities of holding one or more suits of the length indicated are

4	card	suits	0.67
5	"	"	0.46
6	"	"	0.17
7	"	"	0.035
8	"	"	0.005

According to Doctor Levinson one of the finest illustrations of the laws of chance is furnished by the game of poker. He devotes forty-three pages to its analysis, included in which are some valuable new contributions such as:

The better your hand before the draw—straights and flushes barred—the better the chance for the other players to have a good hand. As an illustration of this principle he calculates the probabilities of one pair in a following hand when first hand holds no pair, two pair, three of a kind and four of a kind, to be 0.421, 0.427, 0.431 and 0.444 respectively.

In jack pot the decision to open or pass with a pair of jacks should depend upon the number of players and the nature of the three other cards since the more cards above a jack held the less the chance that the jacks will be beaten. In a six handed game it is a losing play to open on jacks even though the other cards are ace, king, queen. In a five handed game the probability that a pair of queens plus no card above a queen is the highest hand out before the draw is 0.51. This section should be worth many times the cost of the book to any poker player. The author neither advocates nor condemns gambling but does make this cogent statement which might well be studied by our legislators: "Gambling neither creates nor destroys wealth; it affects only its circulation."

Because Doctor Levinson has found errors in previous tables of poker probabilities is no reason that his own are all accurate. The values given in table

eight are all obtainable from Hoyle (The Official Rules of Card Games—Hoyle up-to-date. 36th Ed., U. S. Playing Card Co., Cincinnati, Ohio) except the last five which concern four-flushes and straights. The value given for the four-flush is correct but all of the values for the four-straights are incorrect. The following table gives the probabilities of holding these hands according to Levinson compared with the true probabilities.

	Levinson	True
Four-straight	0.167	0.142
Four-straight open both ends	0.035	0.030
Four-straight open middle	0.123	0.105
Four-straight open one end	0.0087	0.00745

There is a part of the section on poker in which the author tries to show the desirability of assigning a numerical value to such a purely psychological phenomenon as bluffing. Quote: "*A* now raises *B*'s bet $5. *B*, from what he knows of *A*'s game and from the manner in which the latter has played the hand, makes the definite judgment that the probability that *A* is bluffing is 2/5." Could be, but I doubt it.

The last half of the book concerns statistics and their application to business and science. In addition there is a chapter on Doctor J. B. Rhines ESP experiments. The treatment is general and leaves the impression of a sales talk the purpose of which is to interest business men in statistics so that they will employ statisticians. A business equation is mentioned several times but no example of such an equation is given.

It seems to this reviewer that the author becomes somewhat involved in his business section; on one page he says, "in any case, numerically inaccurate formulation is ordinarily a more intelligent basis for action than no formulation," and on the next "To rely on bad statistics is infinitely worse than to rely on no statistics—it may spell ruin."

The book is well printed on good paper but there is no index. If you like to listen to the chips clink you can't afford to be without it.

BART PARK.

CASEIN AND ITS INDUSTRIAL APPLICATIONS, by Edwin Sutermeister and Frederick L. Browne. Second Edition, 433 pages, illustrations, plates, 16 × 24 cms. New York, Reinhold Publishing Corporation, 1939. Price $6.50.

To inform a layman that the buttons on his coat are fashioned from raw material isolated from cow's milk, would certainly be an interesting "believe it or not" story. Yet to those in the business this sort of thing is not so remarkable. The subject of this book is a by-product of the dairy industry, usually prepared from skim milk. The substance has long been used in coatings for paper, water-resistant glues, and insecticide sprays. More recently its uses in the rapidly moving plastics industry and in a number of other industries indicates abundant opportunities for interesting and fruitful study.

This book is in its second edition, the first having been published in 1927. In view of the marked changes that have taken place since then, this edition necessarily contains much revised and considerable new material, although the general plan remains the same. Casein as termed in this book is the substance

from cow's milk, differentiating it from the substance from the milk of other mammals. Further, in this book, casein is a general term that includes paracasein; when it is desired to exclude paracasein the term acid casein is used. The treatment starts with a discussion of casein in milk and the different methods of its isolation, followed by the organic chemistry of casein. The present evidence that casein is a mixture rather than a chemical individual is reviewed in a chapter on the physical chemistry of it. Here, a feature is found which points to the limitations of knowledge of the subject as it now exists. Various possibilities are suggested as to its exact nature and the need for reinterpretation of the literature is mentioned.

A portion of the book is devoted to the changes in manufacture which resulted in improvement of the product since 1927. This includes the equipment required as well as the processes. Testing and analysis for various properties of commercial value is next described which is followed by consideration as to the place and conditions of storage for an extended period of time, from six months to two and one half years. The development of casein plastic material is covered to some detailed extent although aside from the button industry, progress has been slow in the United States. Citations from literature of Europe and America are made with reference to manufacture and formation, but recent European development is not considered, with the exception of mention as to where such information may be obtained.

Casein in glues, paper making, paints, and in the leather industry are all separately taken up before alimentary and medical uses, and miscellaneous uses. At the end of the book a few pages are devoted to statistics on production, imports, and consumption but only in-so-far as to give a rough idea as to the condition of the industry up to and including 1937, and not as to detailed specific information. This is made obvious, since such data is usually supplied from the proper sources periodically.

This American Chemical Society Monograph follows the pattern of other works in the series—a compilation and abstraction of the literature of the world including patent literature, and the molding of this into an account of the present status of the subject. Each chapter is presented by authors who have close association with its coverage. The comprehensive subject index adds greatly to its value.

R. H. OPPERMANN.

AN INTRODUCTION TO CRYSTAL CHEMISTRY, by R. C. Evans. 388 pages, illustrations, 15 × 22 cms. New York, Cambridge University Press, 1939.

The study of crystal chemistry as a science is rapidly becoming more popular for several reasons. Speculations on the internal structure of crystals, based on chemical valency theories, were made long ago and discussed time and again. With the advent of new discoveries in other fields and the resulting means for investigation of crystals, an impetus was given to the study. The most important of these was the use of the X-ray in crystal analysis which threw valuable light on the question of the nature of inter-atomic forces and the atomic configuration of molecules. Today the situation is that crystal structures have been experimentally investigated which range over the whole field of inorganic, organic and even biological chemistry and the study now aims at interpreting the properties of any substance in terms of its crystal structure.

This book is a text of an introductory nature, suitable for chemists with no specialized crystallographic training. It opens with an elementary and purely qualitative account of the nature and properties of the several types of interatomic binding force. The picture brought out of the treatment of the ionic bond as arising from the electrostatic attraction between oppositely charged ions is further considered in a quantitative treatment of the coverage, since the development of the method of X-ray analysis.

A more systematic account of the same field is taken up in Part II which covers the rest of the book, some 276 pages compared with 89 pages in Part I. This section has for its aim the investigation of the relationships which exist between the structure and the chemical constitution of crystalline substances and it begins by illustrating some of the general features of metal structures by reference to those of the metallic elements. Then these features are exemplified in greater detail by a study of the alloy systems. The logic of this order of presentation is shown as offering the practical advantage of enabling the structural characteristics of the metallic bond to be discussed in the first instance in terms of relatively simple systems. Subsequently the topic of the structure of homopolar compounds is discussed, followed by ionic compounds using the conception of the electrostatic valency of a bond as the basis of classification of ionic crystals first before proceeding to the more complex structures where several different cations occur combined with anions of the same or similar types. Ionic compounds of many structures and those containing hydrogen are coverages showing how wide a part of the whole field of inorganic chemistry is included in their study. The topic of molecular compounds completes the book.

The book is an excellent text for those qualified to follow it. It is a review of the field in quite some detail and it reveals the large part of the whole realm of chemical science that falls within the scope of crystal chemistry. References are made to the results obtained by many investigators, throughout the work. At the end there is a bibliography and a subject index.

R. H. OPPERMANN.

PHYSICAL CONSTANTS OF HYDROCARBONS, by Gustav Egloff. Volume I, Paraffins, Olefins, Acetylenes, and other Aliphatic Hydrocarbons. 430 pages, 16 × 24 cms. New York, Reinhold Publishing Corporation, 1939. Price $9.00.

A tremendous amount of research and development work has been performed in the field of hydrocarbon chemistry in recent years, from which there are products both finished and for use in processing. The indications are at the present time that much more can be derived from a knowledge of hydrocarbons. It is now the program to plan a more concerted and orderly attack on the problem and one of the tools in doing this is to have at hand a ready source of physical constants of high order of accuracy and completeness. Of late, efforts have been made in investigation as well as library research to bring together new and existing data on this subject but the work has been widely scattered and incomplete when considering all classes of hydrocarbons.

This book is Volume I of a set of four volumes all belonging to the American Chemical Society Monograph Series. It covers the paraffin, olefins, acetylenes and other aliphatic hydrocarbons, giving a critical review and the most reliable

values of melting point, boiling point, specific gravity and refractive index. The data are obtained from innumerable sources in the literature and unpublished research of many investigators. To realize the immensity of the work, one need only to glance at a few of the pages devoted to a listing of literature sources which are cited, and further, to examine a few to find that not many investigators have given the probable errors of constants, making it necessary to estimate the reliability of the different investigators and their data in order to determine by correlation the most probable values of the constants. This at times required the consideration of all pertinent facts including the mode of synthesis, purification, and measurement; wherever these are given.

The book contains 403 pages of data in tabular form. It represents a noteworthy attempt at collecting all the studies that have been made. Aside from the volume of information given, the gaps where no information is shown, give indication that much is yet to be done in experimentation on certain compounds. The book should be, as it is intended to be, a valuable tool to petroleum technologists and others concerned with hydrocarbon chemistry.

R. H. OPPERMANN.

BERICHT ÜBER DIE 3, INTERNATIONALE TAGUNG DER LEITER GRUBENSICHERHEITLICHER VERSUCHSANSTALTEN IN DORTMUND VOM 23, BIS 28, SEPTEMBER 1935. 312 pages, illustrations, 16 × 25 cms. Gelsenkirchen, Carl Bertenburg, 1939.

For those who are interested in the mechanism of explosions with particular reference to the application to safety in mines this volume will be of value. It reports the sessions of the third conference of its kind (1935), the other two having been held in 1931 and 1933 respectively. Papers were read and discussions made on the subject from many angles by prominent people. Representatives attended the conference from the Westphalia Miners and Employers Associations as well as from interests having to do with experimental and development work in mine safety. Invitations were also extended to other nations including Belgium, France, Poland, Spain, etc., There were some forty participants at the conference. The papers and discussions in this volume are well illustrated with photographs, curves and charts. They are written in German.

R. H. OPPERMANN.

A PREVIEW OF THE ABSOLUTE–RELATIVE THEORY, by Franklin J. Matchette. 26 pages, illustrations, 18 × 26 cms. New York, Author, 1939. Price 50 cents.

Those readers who are interested in the philosophy of science, will find something to think about in this little pamphlet which presents in abbreviated form a theory attempting to throw light upon some of the baffling and ultimate questions to which modern physics seems step by step to be opening the door. The theory unifies in one framework all the various forms of energy known to the physicist, including gravitation; unifies energy with matter; unifies the physical realm of matter and energy with the immaterial realm of mind. These factors are seen as one simple and fundamental entity.

The three basic propositions of the theory are, (1) the relative world is not

self-subsistent, independent, or self-explanatory. It depends for its existance, nature and meaning, upon another realm, the Absolute. (2) The simplest and most basic structural unit of which chemical atoms (and therefore all things) are composed is conceived as the Zero-Atom Unit. It is the only element or unit, or the primordial building block, of the relative world and is endowed with every relative quality found in the world. (3) There is a basic relationship between the Zero-Atom and the Absolute. From it is derivable in a simple way all the manifold and inconceivably complex possibilities of action within the whole relative world.

The condensed form in which the theory here appears, is presented by the author with a view to inviting constructive criticisms, suggestions, and possible collaboration. A fuller and more detailed presentation in book form is planned in the near future.

R. H. OPPERMANN.

DAS CHEMISCHE FEUERLÖSCHWESEN, von Dr. Oskar Kausch. 283 pages, illustrations, 15 × 23 cms. Leipzig, S. Hirzel, 1939. Price 18.50 R.M.

This book is part of the series on the general subject "Chemie und Technik der Gegenwart" edited by Prof. Dr. H. Carlson, which gives accounts on the position and up-to-date developments of various branches of chemistry for the purpose of study as well as explanation of technique. The specialized subject of the present volume is treated in a quite complete manner, being divided into parts on extinguishment with the aid of dry materials, gases and steam, liquids, and foam. Chemical actions and reactions taking place which lead to the desired result, as well as the type, construction and utilization of the various apparatus for fire protection are thoroughly explained. References are made in the treatment to many methods in use with varying results both in Germany and elsewhere, especially to patents of which there is so little compilation. While the book gives a modern account, considerable material of importance which is old is included to reflect the present position of the subject and provide an insight into German conditions. All references made are adequately indexed in the back and there is also a subject index to the text.

R. H. OPPERMANN.

ELECTRON OPTICS, by Otto Klemperer. 107 pages, illustrations, 14 × 22 cms. New York, The Macmillan Company, 1939. Price $1.75.

This little book, one of the Cambridge Physical Tracts, is intended to give a concise account of the most important principles, methods, and applications of geometrical electron optics. In so doing it opens with a historical review of the subject from which there emerges the fundamental principles. With this as a basis, there is pointed out how the cardinal points of an electron lens can be measured and how Gaussian optics is applied to electric and to magnetic lenses. There is also dealt with, the focusing of wide beams and the projection of extended electron pictures. In this connection, a study is made of the main features of the errors of electron lenses. The final chapter deals with some of the most important practical applications of electron optics giving an explanation of the principles of the electron gun, the electron microscope, the picture transformer and the

electron multiplier, the existance of which depend greatly on the science of electron optics. Problems of cylindrical electron optics are treated in the appendix, separated from the former where rotational symmetry alone was considered. A review is given of the uses with special reference to electron valves, multipliers, X-ray tubes with line focus and in some cathode-ray tube constructions such as those employed for sound-film recording.

The book was written partly from a compilation of a great many literary references, a listing of them being included in the back. It fulfills its aim in a manner such as to facilitate understanding by the advanced student of experimental physics or the research worker not specialized in geometrical optics or electron physics.

R. H. OPPERMANN.

PROCEEDINGS OF THE SIXTH SUMMER CONFERENCE ON SPECTROSCOPY AND ITS APPLICATION, HELD AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MASSACHUSETTS, JULY 18–20, 1938. 172 pages, illustrations, 19 × 26 cms. New York, John Wiley & Sons, Inc., 1939. Price $3.00.

Some time ago mention was made in these columns of previous proceedings of these conferences. The book at hand of some 172 pages contains in somewhat abbreviated form thirty-one papers presented during the three days of the sixth conference held at the Massachusetts Institute of Technology in July 1938. Papers on spectroscopy in many branches of science and industry are here recorded including criminal investigation, grasses and plants, medicine, gaseous mixtures, physics and chemistry. What should assist in making this compilation of papers of greater value is the subject index in the back. This is particularly the case when consideration is given to the wide field to which the subject applies and which is covered by the papers.

R. H. OPPERMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

Report No. 654, General Airplane Performance, by W. C. Rockefeller. 25 pages, illustrations, 23 × 29 cms. Washington, Government Printing Office, 1939. Price 10 cents.

Equations have been developed for the analysis of the performance of the ideal airplane, leading to an approximate physical interpretation of the performance problem. The basic sea-level airplane parameters have been generalized to altitude parameters and a new parameter Ω_σ has been introduced and physically interpreted.

The performance analysis for actual airplanes has been obtained in terms of the equivalent ideal airplane in order that the charts developed for use in practical calculations will for the most part apply to any type of engine-propeller combination and system of control, the only additional material required consisting of the actual engine and propeller curves for the propulsion unit.

Finally, a more exact method for the calculation of the climb characteristics for the constant-speed controllable propeller is presented in the appendix. This method replaces the approximate method, contained in the main body of the paper, in cases where the approximate method is not sufficiently accurate.

PUBLICATIONS RECEIVED.

Les Nouvelles Méthodes du Calcul des Probabilités, par Louis Bachelier. 69 pages, 17 × 29 cms. Paris, Gauthier-Villars, 1939. Price 25 fr.

The Social Function of Science, by J. D. Bernal. 481 pages, plates, tables, 15 × 22 cms. New York, The Macmillan Company, 1939. Price $3.50.

Elektrische Höchstspannungen, by A. Bouwers. 333 pages, illustrations, 17 × 25 cms. Berlin, Julius Springer, 1939. Price 31.20 R.M.

Problems in Mechanics, by G. B. Karelitz, J. Ormondroyd and J. M. Garrelts. 271 pages, illustrations, 16 × 24 cms. New York, The Macmillan Company, 1939. Price $2.50.

Your Chance to Win: The Laws of Chance and Probability, by Horace C. Levinson. 343 pages, 15 × 22 cms. New York, Farrar & Rinehart, Inc. Price $2.50.

Sparks, Lightning, Cosmic Rays, An Anecdotal History of Electricity, by Dayton C. Miller. 192 pages, illustrations, plates, 15 × 22 cms. New York, The Macmillan Company, 1939. Price $2.50.

Elements of the Topology of Plane Sets of Points, by M. H. A. Newman. 221 pages, illustrations, 15 × 23 cms. New York, The Macmillan Company, 1939. Price $3.50.

Introduction to Atomic Physics, by Henry Semat. 360 pages, illustrations, 15 × 22 cms. New York, Farrar & Rinehart, Inc. Price $3.50.

Fabre and Mathematics and other Essays, by Lao Genevra Simons. 101 pages, 13 × 20 cms. New York, Scripta Mathematica, 1939. Price $1.00.

Protons, Neutrons, Neutrinos, leçons professées au collège de France, par Jacques Solomon. 228 pages, illustrations, 17 × 25 cms. Paris, Gauthier-Villars, 1939. Price 100 fr.

The March of Mind, by F. Sherwood Taylor. 320 pages, illustrations, 15 × 23 cms. New York, The Macmillan Company, 1939. Price $3.00.

Theoretical and Applied Electrochemistry, by Maurice de Kay Thompson. Third Edition, 535 pages, illustrations, 15 × 22 cms. New York, The Macmillan Company, 1939. Price $5.00.

Kinetik der Phasenbildung, by Dr. Max Volmer. 220 pages, illustrations, tables, 16 × 23 cms. Leipzig, Theodor Steinkopff, 1939. Price 15 R.M.

Textbook of Organic Chemistry, by E. Wertheim. 830 pages, illustrations, plates, 16 × 24 cms. Philadelphia, P. Blakiston's Son & Co., Inc. Price $4.00.

Canada, Department of Mines and Resources. Investigations in Ore Dressing and Metallurgy, July to December, 1937. 137 pages, illustrations, tables, 17 × 25 cms. Ottawa, King's Printer, 1938.

Canada, Department of Trade and Commerce. Coal Statistics for Canada for the calendar year 1937. 110 pages, tables, 17 × 25 cms. Ottawa, King's Printer, 1939. Price 25 cents.

La Structure et la Déformation des Solides, par R. L'Hermite. 50 pages, plates, illustrations, 17 × 26 cms. Paris, Hermann & Cie, 1938. Price 18 fr.

Essais des Métaux, par R. L'Hermite. 70 pages, plates, illustrations, 17 × 26 cms. Paris, Hermann & Cie, 1938. Price 21 fr.

The Problem of Plateau, by Jesse Douglas. 7 pages, 17 × 25 cms. New York, Scripta Mathematica. Price 10 cents.

The Duplicity of Logic, by Edward V. Huntington. 14 pages, illustrations, 17 × 25 cms. New York, Scripta Mathematica. Price 20 cents.

National Advisory Committee for Aeronautics. Technical Notes: No. 705, Wind-Tunnel Investigation of Ground Effect on Wings with Flaps, by Isidore G. Recant. 25 pages, illustrations. No. 706, An Experimental Investigation of the Normal Acceleration of an Airplane Model in Gust, by Philip Donely. 36 pages, illustrations. No. 708, A Simplified Method for the Calculation of Airfoil Pressure Distribution, by H. Julian Allen. 16 pages, illustrations. No. 709, A Semi-Graphical Method for Analyzing Strains Measured on Three or Four Gage Lines Intersecting at 45°, by H. N. Hill. 8 pages, illustrations. No. 710, A Comparison of Ignition Characteristics of Diesel Fuels as Determined in Engines and in a Constant-Volume Bomb, by Robert F. Selden. 11 pages, illustrations. No. 711, An Approximate Spin Design Criterion for Monoplanes, by Oscar Seidman and Charles J. Donlan. 11 pages, illustrations. 6 pamphlets, 20 × 26 cms. Washington, Committee, 1939.

Bell Telephone System, Monographs: B-1121, Adherence of Organic Coatings to Metals, by A. E. Schuh. 11 pages, illustrations. B-1122, A New Apparatus for Microsublimation, by Beverly L. Clarke and H. W. Hermance. 7 pages, illustrations. B-1123, Some Contemporary Advances in Physics—XXXII. Particles of Cosmic Rays, by Karl K. Darrow. 28 pages, illustrations. B-1125, Electrostatic Electron-Optics, by Frank Gray. 31 pages, illustrations. B-1127, Equivalent Modulator Circuits, by E. Peterson and L. W. Hussey. 17 pages, illustrations. B-1130, The True Temperature Scale of an Oxide-Coated Filament, by C. H. Prescott, Jr., and James Morrison. 6 pages, illustrations. B-1132, Exploration of Pressure Field around the Human Head during Speech, by H. K. Dunn and D. W. Farnsworth. 37 pages, illustrations. B-1133, Metal Horns as Directive Receivers of Ultra-Short Waves, by G. C. Southworth and A. P. King. B-1134, Further Investigation of the Chain Structure of Linear Polyesters, by C. S. Fuller and C. J. Frosch. 12 pages, illustrations. B-1135, Adsorption of Water by Papers at Elevated Temperatures, by C. C. Houtz and D. A. McLean. 13 pages, illustrations. 10 pamphlets, 15 × 23 cms. New York, Bell Laboratories, 1939.

CURRENT TOPICS

Forest Service Develops Bell Ringing Radio Device.—A new bell ringing device which permits emergency radio calls to be put through as easily as telephone calls, has been developed in the Forest Service Radio Laboratory at Portland, Oregon. This standby unit has been developed for the new Type T ultra-high frequency radio set, which is a semi-portable outfit operating on 30,000 to 40,000 kilocycles. Any Forest Service ultra-high frequency radio set, however, even the lightest 8 lb. portable, can call a lookout or other station equipped with this bell ringing device. Planned primarily for use at fire lookout towers, ranger and dispatcher stations, this device will eliminate the constant noise from loudspeakers when operators are "standing by"—a noise especially annoying during telephone conversations. Lookouts and other forest officers will no longer need to stay close by their radio sets waiting for calls, as the device may be adjusted to carry signals to men working outside their stations. Less expenditure is involved in this bell ringing system than in the usual loudspeaker development. The battery consumption is so low that 24 hour operation can be afforded. It is believed that this is the first time that bell ringing has been incorporated in truly portable, dry battery operated radio equipment.

R. H. O.

On the Origin of the Earth's Magnetic Field.—WALTER M. ELSASSER in the *Physical Review*, Vol. 55, No. 5, traces the terrestrial field to the existence of thermoelectric currents in the metallic interior of the earth. The currents owe their existence to inhomogeneities continually created by turbulent convective motions. In order to obtain a non-vanishing resultant angular momentum of the currents around the earth's axis, the current system must exhibit a particular asymmetry. The latter is shown to originate through the preponderant influence of the Coriolis force upon the convective motions. The well-known proof, based on potential theory, of the fact that the currents must flow inside and not outside the earth, is briefly reproduced. An analysis of the formal expression for the current density is given. By means of a development in spherical harmonics the conditions for a non-vanishing current momentum can be formulated. It appears that temperature

fluctuations in an otherwise homogeneous medium always yield a zero momentum, therefore the existence of inhomogeneities in the material is also required. It is pointed out that geophysicists have previously obtained evidence of the existence of a metallic core of the earth in which the viscosity is extremely low as compared to the viscosity of the rocks. Radioactive impurities which are very small compared to the total radioactivity of the earth are sufficient to maintain thermally driven convective motions in the metallic core. An estimate of the various terms in the hydrodynamic equations shows that the Coriolis force is much larger than all other dynamical effects. He discusses the effect of the Coriolis force in producing that particular asymmetry which leads to a resultant angular momentum of the currents. It is shown that the inhomogeneities in material required can be accounted for by phase transformations of the material induced by the pressure changes which are connected with the vertical component of the motions. An attempt is made to estimate numerically the current density, basing the estimate on some general results of the theory of conductivity. For temperature variations of the order of 10° the calculated value of the current is in satisfactory agreement with the observed magnitude of the earth's magnetic moment. He discusses the bearing of these ideas upon the magnetism of sunspots.

R. H. O.

Proteins in Alfalfa.—Proteins in alfalfa as a raw material for plastics manufacturing will be studied at Michigan State College, East Lansing, Michigan, as a part of the Rackham Fund Grant activities, according to V. R. Gardner, director of the Michigan Agricultural Experiment Station. Dr. Paul Morgal, formerly of the General Chemical Company, will have charge of the alfalfa project. The study will cover the chemistry of the alfalfa proteins in relation to plastics. Other studies to be undertaken through the Rackham Grant include the development of materials to spray on plants which will reduce transpiration, thus protecting crops in drought or dry areas. This study will be under the direction of Dr. H. G. Petering, formerly of the University of Wisconsin. Graduate students also will assist in the various research projects. Wetting agents for soils will be included in other studies planned for the college laboratories.

R. H. O.

U. S. Scientists Make Rubber-Like Substance from Dairy Bi-Products.—Scientists of the Bureau of Dairy Industry have

perfected a process for making a transparent rubber-like substance from lactic acid of whey that has many promising uses in various industrial operations. Known to chemists as polymethylacrylate, the water-white semi-solid material is closely related to the so-called organic glass made synthetically and used for highway reflectors. It is softer and more flexible than organic glass, however, but is very tough and elastic. Laboratory results obtained by Lee T. Smith and H. V. Claborn, chemists in the Bureau, indicate that polymethylacrylate can be produced as cheaply from lactic acid by their method as it is now produced from ethylene or alcohol by the cyanhydrin process. The Bureau scientists believe the cheapness of their process will contribute to the increased use of lactic acid. Because of their unique properties, polyacrylates are already in demand for various purposes. Their transparency, elasticity, toughness, ease of solubility, and stability to sunlight and ultraviolet rays make them especially valuable in the preparation of lacquers, varnishes, inks, impregnating compounds, and cements. The polymethylacrylate has an additional use as a supporting material, as in motor mountings. Unlike the related organic glass material, polymethylacrylate alone is not suitable for making molded objects, either by the compression or injection method; but it can be combined with the organic glass to make a molding material superior to any of the original compounds. The Dairy Bureau's interest in finding new uses for lactic acid arises from the fact that lactic acid can be made efficiently from the lactose, or milk sugar, of whey. Whey is a byproduct of the dairy industry, both in the manufacture of cheese from whole milk and the manufacture of casein from skim milk. More than 6½ billion pounds of whey is produced in the United States annually. Most of it is used inefficiently, or actually discarded. More than 5 million pounds of lactic acid was produced in this country last year from all sources.

R. H. O.

The Utilization of Aliphatic Nitro Compounds.—K. JOHNSON with ED. F. DEGERING, Purdue University, Lafayette, Ind., in a paper before the recent meeting of the American Chemical Society stated that recent developments in the vapor-phase nitration of the paraffin hydrocarbons by Hass and co-workers have indicated that the nitroparaffins may be cheap and important raw materials. In this study, all the nitroparaffins available from the nitration of butane, isobutane, and propane have been reduced to the corresponding amines by the use of iron and hydrochloric acid and by catalytic hydrogenation. These processes produce good yields of easily purified products, and require only simple technique and

standard apparatus except for the Parr bomb required for the hydrogenation. The results obtained indicate that primary, secondary, and tertiary nitro compounds can be reduced to give almost quantitative yields of the corresponding amines. The conversion of nitroparaffins to oximes gives, in general, rather low yields due to the simultaneous formation of amines.

R. H. O.

Pentachlorophenol for Wood Preservation.—This is the title of a paper recently presented before the American Chemical Society by T. S. CARSWELL and IRA HATFIELD, Monsanto Chemical Co., St. Louis, Mo. Inherent differences in wood being manufactured into lumber today coupled with more severe use conditions, call for the production of a suitable new wood preservative. Changes in architectural designs, the tendency to "finish" and heat basements, and the advent of air conditioning makes it imperative that wood be amply protected against decay and termities. Pentachlorophenol in suitable solvents has been found to exhibit valuable protective qualities when properly applied to wood and wood products. Treatments using suitable solvents have not adversely affected fabrication or the paintability and puttyability of the treated wood. Physical, chemical, and toxicological data are briefly presented. Laboratory data on solubility of pentachlorophenol in organic solvents is given and considerable laboratory data on biological tests are presented. A review of the field application test work is given, and suggestions are made as to the field of usefulness of pentachlorophenol for wood preservation.

R. H. O.